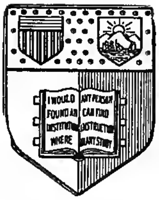
Preservation
Seasoning
Timber Physics

C. H. Guise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U. S. Department of Agriculture, Forest Service

FOREST PRODUCTS LABORATORY

In cooperation with the University of Wisconsin
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List of publications on

KILN DRYING
PHYSICAL PROPERTIES OF WOOD
WOOD STRUCTURE

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PUBLICATIONS ON KILN DRYING AND PHYSICAL PROPERTIES

Mimeographed Circulars and Reprints

Copies of mimeographed reprints and circulars covering certain phases of kiln drying will be sent free upon application to the Director, Forest Products Laboratory, Madison, Wisconsin, as long as the supply lasts. Orders for a large number of reprints and circulars on a variety of subjects will not be filled except in special cases.

Brain Work in Kiln Operation
How to Measure Conditions in Seasoned Lumber
Stresses and Detection of Casehardening During Kiln Drying
Steaming Lumber Before and During Kiln Drying
Drying Schedules for Hardwoods for Furniture and General Interior Use
Schedules for Drying Softwoods
General Kiln-Drying Process for Seasoning Certain Kinds of Lumber without Reduction in Strength Properties
Suggestive Specifications for Kiln Drying Process for Seasoning Woods to be Used in the Manufacture of Furniture and Similar Products where Maximum Strength of the Wood is of Secondary Consideration
Brief Synopsis in Regard to the Kiln Drying of Oak for Wagon Stock; Including Mention of Hickory, Elm, Birch, and Maple.
Kiln Drying of Woods for Airplanes
The Effect of Kiln Drying on the Strength of Airplane Woods
Discussion of Specifications for Kiln Drying Wood for Airplane Uses
The Kiln Drying of Red Gum
Experiments in Kiln Drying Southern Yellow Pine
Drying of Plywood Panels
~~The Improved Water Spray Humidity Regulated Dry Kiln~~
Notes on the Operation of the Forest Service Water Spray Dry Kiln and Theoretical Considerations of Heat Relations

Kiln Drying Systems Compared; Relative Virtues of Progressive and Compartment Methods.
Drying Lumber by Means of Superheated Steam
Design for Forest Service Superheated Steam Dry Kiln
Calculation of Steam Consumption in Drying One-inch Douglas Fir in Forest Service Superheated Steam Dry Kiln
Recording Thermometers
Relation of Moisture Content and Drying Rate of Wood to Humidity of the Atmosphere
Shrinking and Swelling of Wood
Shrinkage of Interior Trim: Its Cause and Prevention
Inadequacy of Visual Inspection in Kiln Drying
The Handling, and Storing, and Care of Spruce Airplane Stock
Sap-Stain and Molds on Lumber
Factors Affecting the Strength of Wooden Members
List of Dry Kiln Manufacturers and Engineers
Eucalyptus Lumber

Technical Notes

A-1	Hints on Storing Lumber to Prevent Decay
B-11	Method of Determining Moisture Content of Wood
B-12	Shrinkage in So-Called "Compression Wood".
B-15	Average Weights of Various Species of Wood
D-1	Steaming of Vehicle Stock During Kiln Drying
D-3	Built-up Artificial Limb Blanks
D-4	Circulation and Piling in the Dry Kiln
D-5	Correct Moisture Content of Lumber
D-7	Quarter-Sawed Oak Chair Posts at Plain-Sawed Prices
D-8	Coatings that Prevent End Checking
D-9	Flat Panels and No Surface Checks by Maximum-Humidity Method
D-10	Piling Oak Dimension to Reduce Season Checks
D-12	Uneven Coatings on Wood Cause Warping
D-13	Casehardened Lumber and Warped Products
D-14	How to Accomplish Rapid Kiln Drying
D-15	A Drying Schedule for Air-Seasoned Oak
F-1	Foreign Trade in Furniture
F-8	Moisture Content of Wood at Different Humidities
F-24	Moisture Absorption Through Varnish Same for Different Species of Wood
F-27	Comparison of Moisture Resistance Tests for Coatings
F-33	Comparative Durability of Green and Seasoned Timber
85	Shrinkage of Veneer from Boiled and Steamed Logs
89	Moisture Content of Wood is Independent of Density
90	Kiln Drying of Green Hardwoods Requires Mechanically Perfect Heating System
107	Drying Periods for Various Woods
111	Drying by Superheated Steam
112	How to Tell When Lumber is Ready to Remove from the Kiln
121	Automatic Humidity Control in Shops
124	Materials Used in Dry Kiln Construction
127	Smoke Making Device for Testing the Circulation in Dry Kilns.

Government Bulletins and Circulars

	Date of Issue
The Seasoning of Wood, U.S.D.A. Bulletin 552 - 10 cents	July 9, 1917
Principles of Drying Lumber at Atmospheric Pressure and Humidity Diagram, F.S. Bulletin 104 - 5 cents	Dec. 16, 1912
The Theory of Kiln Drying, U.S.D.A. Bulletin 509 - 5 cents	Mar. 1917
Timber Storage Conditions in the Eastern and Southern States With Reference to Decay Problems, U.S.D.A. Bulletin 510 - 20 cents.	May, 1917
Manual of Design and Installation of Forest Service Water Spray Dry Kiln, U.S.D.A. Bulletin 894 - 10 cents.	Oct. 18, 1920
Effect of Moisture on the Strength and Stiffness of Wood, F.S. Bulletin 70 - 15 cents	1906
Strength of Wood as Influenced by Moisture, F.S. Circular 108 - 5 cents	1907
°Density of Wood Substance and Porosity of Wood, Published in Journal of Agricultural Research 25 cents	Sept. 21, 1914

°Indicates supply is exhausted.

Note - None of the above publications are available for general distribution from the Forest Products Laboratory. These publications can be obtained from the Superintendent of Documents, Government Printing Office, Washington, D.C., at the price stated, until the supply is exhausted. Remittances should be made by money order, or in coin (at sender's risk); stamps cannot be accepted. Publications out of print can be consulted at public libraries. In a number of cases they have been superseded by more recent publications.

	Date of Issue
Materials for the Household; Bureau of Standards Circular 70 (Contains a chapter on Wood) - 25 cents	Dec. 5, 1917
Timber, Elementary Discussion of Characteristics And Properties of Woods of North America; F.S. Bulletin 10, 10 cents.	1895

Other Publications

The Kiln Drying of Lumber - by H. D. Tiemann, Third Edition, 1920. Obtainable from H. D. Tiemann, Forest Products Laboratory, Madison, Wisconsin, or from the publishers of J. B. Lippincott & Co., Philadelphia. $4.50 Net.

The Kiln Drying of Lumber - Correspondence-Study Course Given by the Extension Division of the University of Wisconsin, Madison, Wisconsin. $5.00

Timber, Its Strength, Seasoning, and Grading - H.S.Betts, 1919. McGraw-Hill Book Co., New York, $3.10.

Papers Prepared by the Forest Products Laboratory and Published in Proceedings of Societies; Trade, Technical and Other Journals

Kiln Drying

Title	Author	Where published	Date
Kiln Drying Systems Compared	Tiemann, H.D.	Hardwood Record	Sept.10, 1920
Kiln Drying of Woods for Airplanes	" " "	National Advisory Committee for Aeronautics	1920
The Effect of Kiln Drying on the Strength of Airplane Woods	Wilson, T.R.C.	National Advisory Committee for Aeronautics	1920
Drying Lumber By Means of Superheated Steam	Tiemann, H.D.	Southern Lumberman	May 1, 1920
Good and Bad in Kiln Drying	Sweet, C. V.	Southern Furniture Mfgrs. Ass'n.	March, 1920
Drying of Plywood Panels	Brewster, D.R.	Furniture Mfgr. and Artisan Hardwood Record	May, 1920 July 25, 1920
Shrinking and Swelling of Wood	Koehler, Arthur	Furniture Manufacturer and Artisan	March, 1920
Preventing Shrinkage of Interior Trim	Teesdale, L.V.	Building Age American Architect House Beautiful	July,'19 July,'19 Sept.'19
°The Phenomena of Drying Wood	Tiemann, H.D.	Jour. of Franklin Institute	July,'19
°An Analogistic Explanation of Casehardening	" " "	" "	May,1920

Title	Author	Where published	Date
°Kiln Drying Specifications for Lumber	Tiemann, H. D.	Hardwood Record Sci. Am. Supp.	June 10, 1919 Aug.16, 1919
Inadequacy of Visual Inspection in Kiln Drying	" " "	Aviation and Aeronautical Engineering	June 18, 1919
Relation of Moisture Content and Drying Rate of Wood to Humidity of Atmosphere	Koehler, Arthur	American Lumberman	July 12, 1919
°Proper Care of Airplane Wood	Hallauer, F. J.	Timberman	June, '19
Brain Work in Kiln Operation	Sweet, C. V.	West Coast Lumberman Hardwood Record	June 1, 1919 May 10, 1919
°How to Dry Red Cedar to Avoid Collapse	Tiemann, H. D.	West Coast Lumberman	Mar.15, 1919
Experiment in Kiln Drying Southern Yellow Pine	Imrie, J. E.	Am. Lumberman St.Louis Lumberman Lumber Trade Journal	Sept.1, 1917 Sept.1, 1917 Sept.1, 1917

Note - The mark before the name of an article indicates that no reprints are available for distribution. Such articles must be consulted in the original publication. Of the other articles, a limited supply of reprints are available for general distribution, and copies will be sent free upon application until the supply is exhausted. Application should be made to Director, Forest Products Laboratory, Madison, Wis.

Title	Author	Where Published	Date
Measuring Conditions in Seasoned Lumber	Imrie, J. E.	So. Lumberman Hardwood Record Am. Lumberman Lumber Trade Journal	Mar.10'17 " " Mar.15. 1917
°Drying in Superheated Steam	Tiemann, H.D.	Lumber World Review	Aug.10, 1916
°The Casehardening of Wood	" " "	Lumber World Review	July 10, 1916
°The Circulation in Dry Kilns; Parts 1,2,3, and 4.	" " "	Lumber World Review	May 10, '16 to Aug.10, 1916
°Kiln Drying of Gum	Imrie, J. E.	Am. Lumberman So. Lumberman Hardwood Record Am. Furniture Mfr.	Jan. 22 Jan. 22 Jan.25 1916
°Conditions Which Exist Casehardened Wood	Imrie, J. E.	Hardwood Record Am. Lumberman	Nov.10, Nov.13, 1915
°The Kiln Drying of Lumber	Tiemann, H. D.	St. Louis Lumberman Am. Lumberman So. Lumberman	Nov. 1 Oct.30 Oct.25, 1915
°Improvement in Forest Service Humidity Regulated Dry Kiln	Tiemann, H. D.	Am. Lumberman Hardwood Record	Sept.1 Sept.5 Sept.25, 1915
°Problems in Kiln Drying Lumber	Tiemann, H. D.	Lumber World Review	Sept.25, 1915
°Effect of Different Methods of Drying on the Strength of Wood	Tiemann, H. D.	Lumber World Review	April 10 1915

Title	Author	Where Published	Date
°Principles of Kiln Drying Lumber, Part 1 Part 2	Tiemann, H.D.	Lumber World Review	Jan.25 Feb.10 Feb.25 1915
°How to Dry Western Larch	Tiemann, H.D.	West Coast Lumberman	1914
°Kiln Drying Lumber and a Discussion of the Whole Problem - A New Kiln	Tiemann, H.D.	Lumber World Review	Mar.10, 1914
°Air Seasoning of Timber From Paper Contributed to Bul. 161, American Ry. Eng. Ass'n.	Kempfer, W.R.	Railway Review	Jan.10, 1914
°Kiln Drying of Lumber Scientifically Considered	Tiemann, H.D.	American Lumberman	Nov.15, 1913
Eucalyptus Lumber. Part 1. To What Extent is California Grown Eucalyptus Suitable for Lumber? 2. Results of Experiments in Drying Blue Gum and Other Species	Tiemann, H.D.	Hardwood Record	Sept.25, 1913
°Is Eucalyptus Suitable for Lumber?	Tiemann, H.D.	Proc. Soc. of Am. Foresters	Oct., 1913

Physical Properties

Title	Author	Where Published	Date
°Microscopy on Pulp and Paper Woods	Gerry, E.	Paper	Apr.21, 1920
Selecting Wood for Airplanes	Koehler, A.	Scientific Am. Supplement	Sept.6, 1919
°Effect of Moisture and Other Extrinsic Factors on the Strength of Wood	Tiemann, H.D.	Society of Am. Foresters Proceedings - '07	1907

PUBLICATIONS ON WOOD STRUCTURE

Mimeographed Circulars, Reprints and Technical Notes[o]

How to Distinguish Douglas Fir From Sitka Spruce
The "Grain" of Wood with Special Reference to the Direction of the Fibers
Key for the Identification Without the Aid of a Hand Lens of Native Woods Used for Chairs and Other Furniture
Key for the Identification Without the Aid of a Hand Lens of Woods Used for Box and Crate Construction
How to Separate Black Ash from Commercial White Ash Lumber
The Identification of True Mahogany and Certain So-Called Mahoganies

Technical Notes[o]

D-2	How to Distinguish Douglas Fir from Sitka Spruce Lumber
D-11	How to Distinguish Black Ash from Commercial White Ash Lumber
95	The Length of Wood Fibers
103	How to Distinguish Mahogany and Walnut from Red Gum
116	How to Tell Birch, Beech and Maple Apart
125	Identification of Oak Woods

Government Bulletins and Circulars[oo]

	Date of Issue
Guidebook for the Identification of Woods Used for Ties and Timbers; Misc. F.S. Bulletin, 30 cents.	Oct.,1917
Tyloses: Their Occurrence and Practical Significance in Some American Woods -- Journal of Agricultural Research; 25 cents.	May 25, 1914

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[o] Available at the Forest Products Laboratory.

[oo] Obtainable only from the Superintendent of Documents, Government Printing Office, Washington, D. C.

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Papers Prepared by the Forest Products Laboratory and Published in Proceedings of Societies; Trade, Technical and Other Journals

Title	Author	Where Published	Date
American Storax Production: Results of Different Methods of Tapping Red Gum Trees.	Gerry, Eloise	Journal of Forestry	Jan., 1921
Production of American Storax	Mahood, S.A. Gerry, Eloise	Druggists Circular	Jan., 1921
°Bordered Pits in Douglas Fir: A Study of Position of Torus in Mountain and Lowland Species in Relation to Creosote Penetration	Griffin, G.J.	Journal of Forestry	Nov., 1919
The "Grain" of Wood With Special Reference to the Direction of the Fibers	Koehler, A.	Aerial Age Weekly West Coast Lumberman Scientific Am. Supplement	Aug. 12, 1918 July 15, 1918 Sept. 7, 1918
° Proper Methods of Turpentining Increased Yield Obtained Without Serious Injury to the Tree	Gerry, Eloise	Scientific Am. Supplement No. 2176	Sept. 15, 1917
°A Plea for Closer Discrimination in the Use of the Words "Grain" and "Texture" With Respect to Wood	Koehler, A.	Hardwood Record	Feb. 25, 1917
°Fiber Measurement Studies A Comparison of Tracheid Dimensions in Longleaf Pine and Douglas Fir, with Data on the Strength and Length, Mean Diameter and Thickness of Wall of Tracheids	Gerry, Eloise	Science N.S. Vol XLIII, No. 1106	Mar. 10, 1916

Title	Author	Where Published	Date
°The Structure of Wood and Some of Its Properties and Uses	Gerry, Eloise	N. Hem. & Hardwood Ass'n.	Jan., 1916
°Chemistry as an Aid in the Identification of Species	Schorger, A.W	Proc. Soc. of Am. Foresters	Jan., 1916
°Wood Older than the Hills	Koehler, A.	Am. Lumberman Am. Forestry	Dec. 25. 1915 Feb., 1916
°A Visual Method of Distinguishing Longleaf Pine	Koehler, A.	American Lbrman Engineering Rec	Sept. 11 Sept. 11 1915
°Fiber Measurement Studies. Length Variations; Where They Occur and Their Relation to the Strength and Uses of Wood	Gerry, Eloise	Science N.S. Vol XLI, No. 1048	Jan. 29, 1915
°An Improved Method of Infiltrating Wood With Celloidin	Koehler, A.	Proceedings of the Society of American Foresters	April, 1914
°Microscopic Structure of Woods in Relation to Properties	Gerry, Eloise	Proc. Soc. of Am. Foresters	July, 1913
°Microscopic Work of the Laboratory of Forest Products on the Structure of Wood	Tiemann, H.D	Am. Forestry	April, 191[illegible]

OTHER LISTS OF PUBLICATIONS

Obtainable at the Forest Products Laboratory

Publications on Wood Preservation
Publications on Glue, Plywood, and Coatings
Publications on Derived Products
Publications on the Mechanical Properties of Timber
Publications on Pulp and Paper
Short List of Books on Wood
Short List of Government Publications on Wood and Trees, Each Covering a Large Number of Species
Government and State Bulletins on the Marketing of Woodland Products
State Wood-Using Industry Reports
Price List of Government Bulletins and Circulars on Forestry: Tree Planting, Wood Tests, and Lumber Industries.

U. S. Department of Agriculture, Forest Service

FOREST PRODUCTS LABORATORY

In cooperation with the University of Wisconsin

MADISON, WISCONSIN

DRYING OF PLYWOOD PANELS

By D. R. BREWSTER
Forest Examiner

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DRYING OF PLYWOOD PANELS

By
D. R. Brewster
Forest Examiner

The Panel Drying Problem

All of the commonly used types of glue contain a considerable amount of water. When pieces of seasoned wood are glued together enough of this water may be absorbed from the glue so that the total per cent of moisture in the wood is very materially increased. A particularly large increase in moisture content occurs from this absorption in the gluing of thin pieces of wood such as veneer, in which there is a very large amount of absorbing surface compared to the total volume of the wood. For example, birch veneer one-sixteenth inch thick having an original moisture content of eight per cent when glued together into three-ply panels will contain a total of from sixteen to twenty-five per cent moisture after the glue has set, depending upon the kind and amount of glue used, and proportion of water in the glue mixture.

In order to avoid trouble from shrinking, warping, and checking, after wood is put in use, it is essential that the wood be dried down to a moisture content which will

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remain as nearly constant as possible under the atmospheric conditions to which the wood is to be subjected in service. For instance, furniture in heated buildings will come to a moisture content of from approximately 5 to 10 per cent, depending upon the season and climate, while wood used out of doors as in fences and agricultural implements will show an approximate range of from 10 to 15 per cent under varying out door conditions. It is evident then that the moisture content of panels made from dry veneer generally will be high enough after gluing so that some sort of a drying operation will be necessary before the material is ready for use. Such a drying operation will be even more necessary if the panels are made up of green or partially green veneer as is sometimes done, since not only the moisture absorbed from the glue but also a substantial part of the original moisture in the green wood must be removed.

The old time-honored method of drying panels and other glued work in wood working factories has been to stack the material in an open pile in one corner of the shop and allow it to dry out very slowly under shop conditions. This operation extends over a period of several days and produces satisfactory results as far as the condition of the material is concerned. However, in large factories where space is limited and it is desirable to

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speed up production and practice economy in every possible way, this method is much too slow and expensive. Consequently, there has developed during recent years, particularly in connection with the large scale manufacture of panels for aircraft during the war, a need for some method of drying panels artificially which will do the work in the minimum length of time that is possible without injury to the material and with the least cost.

Various wood working factories and manufacturers of drying apparatus have worked on this problem and have tried out a number of different methods of drying the panels in artificially heated chambers or drying machines with more or less satisfactory results. Temperatures ranging from 90 to 225 degrees Fahrenheit with various per cents of atmospheric moisture and wide variations in length of the drying period were embraced in these different methods, and the advantages claimed were more or less inconsistent and conflicting.

Scope and Purpose of Study

To meet the evident need for more complete and authoritative information on the drying of panels, an intensive study of the problem was undertaken as part of a general investigation covering conditions affecting the manufacture of plywood in aircraft construction made by

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the Forest Products Laboratory of the United States Forest Service, at Madison, Wisconsin. This study was planned specifically to determine the optimum temperatures, humidities and other drying conditions that should be used in drying representative kinds of plywood panels, particularly waterproof panels used in aircraft construction, in order to accomplish the drying in the shortest possible time consistent with obtaining maximum strength and water resistance of the glue joints, avoiding injury from surface checking, warping, and opening of face joints, and employing a safe, convenient and economical method of kiln operation.

Summary and Recommendations

A total of 78 separate drying tests were made during the course of this study, arranged in 12 series, and including 35 different drying treatments. Several representative types of panels made from different species of wood and glued with commercial casein Laboratory No. 4 casein, blood albumin and vegetable glues, were dried and it is thought that the work has covered the ground with sufficient thoroughness to justify the making of fairly definite recommendations as to desirable methods of drying panels.

1. Temperatures and Humidities

For general use in drying any ordinary type of panel, the results of this study indicate that the essential requirements of minimum injury to the material, a sufficiently rapid drying rate, and convenience and economy of operation can best be met by maintaining a constant temperature of about 120 degrees in the drying chamber with a constant "maximum" relative humidity which will permit the stock to dry down to the final degree of dryness desired but which will not allow an appreciable amount of further drying below the required moisture content. The relative humidities which will dry the stock down to final moisture contents of from 8 to 12 per cent in a practicable length of time with temperatures ranging from 100 to 180 degrees Fahrenheit are given in the following table:

Table of Relative Humidities which when used with Different Temperatures, will dry Panels to Various Approximately Constant Moisture Contents in a Practicable Period of Time

Final Moisture Content Desired	Per Cent Relative Humidity For Use With Different Temperatures								
	100°F	110°F	120°F	130°F	140°F	150°F	160°F	170°F	180
8 Per Cent	37%	39%	42%	44%	46%	49%	51%	53%	55
9 " "	44	46	48	50	53	55	57	60	6
10 " "	50	52	54	56	58	60	62	64	67
11 " "	55	57	59	61	63	65	68	70	72
12 " "	60	62	64	66	68	70	72	74	76

Using these standard conditions, the drying time for 1/4-inch three-ply panels will vary from about 8 to 16 hours depending upon the final moisture content desired and the original moisture content of the panels.

Temperatures lower than 120 degrees do not produce any less checking or warping than do the treatments at around 120 degrees nor is any consistent increase in the strength or water resistance of the glue joints obtained at the lower temperatures. On the other hand, the time of drying is materially lengthened when temperatures lower than 120 degrees are used.

Temperatures above 120 degrees have the advantage of decreasing the drying time, but in many cases, especially where dry veneer is used, these temperatures show a distinct tendency to lower the strength or water resistance of the glue joints and to increase checking and warping, particularly above 140 degrees. The difference in these respects between 120 degrees and 140 degrees is very slight but is sufficient to justify recommending the use of the lower temperature where panels of the highest grade are desired. Where increased speed of drying is highly desirable it may, of course, be obtained by increasing the temperature but will be accompanied by an increased risk of injury to the stock.

The range of temperatures that can be used safely in drying panels varies with the kind of glue and the original moisture content of the veneer before gluing. Where a certain amount of warping is not objectionable panels glued with commercial casein or Laboratory No. 4 casein glue may be dried with temperatures of 167 degrees or higher without injury to the glue joint, provided that veneer is used which has not been pre-dried and which has a moisture content of at least 20 per cent before gluing. On the other hand, blood albumin glue when used with such moist veneer shows a distinct deterioration of the glue joint with these higher temperatures. Where casein glue is used with pre-dried veneer of 8 per cent moisture content, however, panels dried at 140 and 160 degrees show distinctly less strength and water resistance of the glue joint than those dired at 120 degrees or lower. A temperature of 120 degrees is recommended for general use because it seems to be equally suitable for all species and thicknesses of panels and all of the kinds of glue studied, -- commercial, casein, Laboratory No. 4 casein, blood albumin, and vegetable.

The maintenance of constant temperatures and humidities in the drying chamber is recommended for greatest safety, simplicity and flexibility in the drying operation. The work of regulating thermostats or other means of control is reduced to a minimum and the services of a specially

trained operator are not required for safe regulation. Furthermore a less expensive type of thermostat or other control can be used and it will have longer life and give more dependable service than where temperatures must be frequently changed over a considerable range during the drying period. With conditions the same at all times undried stock can be put in the drying chamber at any time that is most convenient, thus eliminating lost motion and delay in starting the drying and making it possible to utilize the capacity of the chamber to its fullest extent.

A constant humidity which will not permit the stock to dry below the final moisture content desired, that is, the "maximum humidity" which can be used to obtain this final result has the obvious advantage of giving greater flexibility and convenience as well as safety in handling the stock. The panels will not be exposed to injury from warping and checking due to over-drying, even without special tests of condition or close supervision of the progress of drying. It is therefore possible to leave them in the chamber longer than the minimum period required to dry them down to the desired point. Testing of each set of panels to determine when this final point is reached is consequently unnecessary and the stock can be removed at whatever time is most convenient, provided it has been left in for the minimum drying period required. Thus with a drying period

of from 8 to 16 hours the undried panels may be placed in the drying chamber at any time during one working day and removed at any time that is most convenient during the next working day with the assurance that they will be in the desired condition without the necessity of making special tests.

In drying chambers such as compartment kilns in which conditions are uniform throughout, there are very obvious advantages in being able to maintain the same temperatures and humidities from beginning to end of the drying period. This greatly simplifies regulation of kiln conditions and permits the addition of new stock and the removal of old stock at any time that is most convenient. The results of this study indicate that excellent results can be obtained in drying panels in this way using a temperature of about 120 degrees Fahrenheit and the maximum humidity which will dry the stock to the desired point. While higher humidities during the early stages of the drying might possibly be slightly beneficial, this was not clearly indicated in the experiments and any slight advantage which might result from these higher humidities would be more than offset by the closer attention required in regulating conditions and the lack of flexibility and convenience in operation.

Except in plants which operate both day and night a drying time of from 8 to 16 hours is short enough to permit the drying of all panels made one day before the new panels made the following day are ready to be put in the kiln. Since all panels could safely be left for the full period from the time put in one day until the time taken out the next day the time of from 8 to 20 hours consumed in drying 3-ply panels with the maximum humidity method at temperatures around 120 degrees would permit of limiting kiln capacity to one day's output.

Economy and convenience in operation could possibly be increased under certain conditions and the most ideal kiln conditions obtained by the use of a progressive kiln in which the new panels are put in at one end and the dried panels are removed at the other end. Without sacrificing the advantage of being able to keep the kiln conditions constant, the humidity at the loading end could be kept higher and the temperature possibly lower than at the leaving end thus obtaining whatever benefits there might be from subjecting the fresh panels to milder drying conditions than are used in the final stage. Where the drying period is a matter of hours, however, as with thin panels the use of the progressive idea might necessitate either some automatic means of moving the material forward as is used in drying machines

such as the Coe Dryer, or it might require additional expense for an attendant during the day and possibly the night to move the trucks.

One disadvantage of a progressive kiln having mild conditions at the loading end would be that in drying thin panels a much larger kiln capacity would be required than would be the case with compartment kilns having uniform conditions. In order to complete by the beginning of the second day the drying of all panels loaded one day, the kiln would have to be large enough to accommodate the first day's entire output at the warm end. Or if the entire kiln were kept full at all times the capacity would, unless the plant were kept running night and day, have to be sufficient to take care of the lost motion which would result from having to leave the material in the kiln longer than the minimum time required to complete the drying. For most plants it is believed that greatest economy and satisfaction will be obtained by the use of a drying chamber in which the final humidity is maintained uniformly throughout, from beginning to end of the drying period.

2. Weighting of Panels During Drying to Prevent Warp

Weighting the panels during the drying operation to prevent warping appears of questionable value. A special study involving 18 comparable sets of tests showed

that while in some tests the unweighted panels showed the most warp, in other tests of similar material dried under identical conditions the greatest warp occurred under a heavy pressure of 220 pounds per square foot of pile surface and that in the average of all tests the amount of warp under no pressure, 60 pounds and 220 pounds was practically the same. While this can not be considered absolutely conclusive evidence that weighting does not prevent warping to some extent with ordinary drying temperatures and methods, yet it clearly indicates that weighting is a minor factor in preventing warp and that weighting or other application of pressure to panels during drying will probably not prevent warp to an extent which will justify much of an investment in additional equipment or extra expense in piling.

3. Moisture Content of Veneer Used

The use of moist veneer in building up the panels results in much more warping and surface checking than is obtained when dry veneer is used. This is true regardless of differences in the drying conditions to which the panels are exposed, whether the drying is mild and slow or rapid and severe. Where there is a manufacturing advantage in using moist veneer, this increased warp and liability to checking must be taken into consideration as a disadvantage

which will partially or entirely offset the gain from using moist stock, if ordinary drying temperatures and methods are used.

As an example of an unusual method of drying devised to get around this difficulty the process used in a factory which manufactures cottonwood panels might be mentioned. The 1/16-inch cottonwood veneer is glued dripping wet just as it comes from the log using blood albumin glue. After putting it in a hot press to set the glue, the stock is dried down to about 25 per cent in a drying machine after which the panels are placed in the hot press again one by one and dried to final condition under hydraulic pressure. By this final heating and pressing the material is put in a hot plastic condition and practically molded into the final flat form in which it remains after removal from the press. Some such treatment as this seems almost necessary in the successful manufacture of cottonwood panels but the extent to which it would be adapted to use with other species is questionable and there is a possibility that the strength of the glue joint may be injured in such a process. It is also a slow method which consumes a great deal of steam and requires a large amount of expensive equipment in the way of hot presses, dryers, etc.

4. Density of Veneer Used

The use of cores made of high density wood such as birch or maple results in more warp than is obtained when low density woods such as basswood or yellow poplar are used.

5. Final Moisture Content of Dried Panels

Drying the panels to a comparatively low moisture content also materially increases the warp. In fact the amount of warp was found to increase approximately in inverse proportion to the per cent of moisture in the stock as the panels dried down to a thoroughly dry condition. This relation makes it possible to compare the amount of warp in panels from different runs and of different final moisture contents by means of an intermediate expression termed the "warp coefficient", obtained by multiplying the amount of warp in inches by the moisture content of the panel in per cent.

6. Effect of Unbalanced Construction on Warping

In preventing warping it is essential that the panels be made with what is known as "balanced construction". This means using an odd number of plies, with each pair of plies on either side of the core as nearly alike as possible in species, thickness and grain, and with the grain of each

ply running at right angles or 90 degrees to the grain of adjacent plies. Warping due to unbalanced construction is commonly caused either by laying up the panels with the grain of adjacent plies not at right angles, by the use of different species or thickness of veneer in any pair of plies or by unequal sanding of the surfaces in finishing, making one face thinner than its mate on the opposite side of the panel.

In order to eliminate the effect of unbalanced construction in comparing the effect of different drying conditions on warping special tests were made to determine the exact angle between adjacent plies on 318 of the 3-ply panels included in this study. An analysis of the data shows that variations both from a perpendicular angle between the grain of the faces and the core and from a parallel direction of the grain of the two faces are important causes of warping. To express this double relationship, the "angle deviation factor" was devised. This is the sum of the average deviation from perpendicular between the grain of the faces and the core plus the deviation from parallel between the grain of the two faces. It was found that when this "angle deviation factor" totalled to 9 or more degrees the variation from a balanced construction was sufficient to be considered a major cause of warping,

thus eliminating such panels from a comparison to determine the influence of other variables on warping..

7. Increase in Moisture Content after Gluing

Absorption of water from the glue is sufficient to increase the moisture content of panels glued with casein, or vegetable glue from 8 to 18 per cent depending upon the thickness of the veneer. With blood albumin glue, the increase after placing in the hot press for about 5 minutes and then allowing to cool varied from 5 to 10 per cent, the smaller amount as compared with the other glues being due to the moisture removed by vaporization as the panel cools after removal from the hot press.

8. Opening of Taped Faced Joints in Drying

Differences in drying conditions do not appear to influence the opening up of taped faced joints during drying. Joints which were invisible before drying opened to approximately the same extent with mild slow-drying conditions as with more severe conditions. It was generally found that the joints which did not open up because of drying were those in which a small amount of glue had been forced between the edges of the veneer in the joint when the panel was put in the press. This trouble can evidently be much more easily controlled by gluing the joints than by regulating the drying conditions.

U. S. Department of Agriculture, Forest Service

FOREST PRODUCTS LABORATORY

In cooperation with the University of Wisconsin

MADISON, WISCONSIN

DRYING LUMBER BY MEANS OF SUPERHEATED STEAM

By H. D. TIEMANN
Physicist and Dry Kiln Specialist

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DRYING LUMBER BY MEANS OF SUPERHEATED STEAM

Important Principles to Be Considered in Its Application to Commercial Use -- Description of the Forest Service Superheated Steam Kiln

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The idea of using superheated steam as a medium of drying lumber is an old one, and various processes embodying this principle have been patented and tried. These methods include drying at pressures less than atmospheric (vacuum processes), at atmospheric pressure, and at greater pressures, as well as alternations of pressure.

The main idea in the application of steam (which is the same thing as water vapor in absence of air) for drying lumber seems to have been that the steam should be a "moist heat," whereas air was "dry." As a matter of fact, steam when superheated, may be just as dry as air, depending upon its temperature and pressure, but with this difference: when steam is "saturated" (which occurs at 212 degrees F, at standard atmospheric pressure) it is indeed moist, being in a

condition of 100 per cent relative humidity; but when it is heated above this temperature, at atmospheric pressure, it becomes dry and behaves like any other gas. Thus, at 273 degrees F. steam at atmospheric pressure is very dry and equivalent to a relative humidity of only 50 per cent. As it cools, however, which it does very rapidly in contact with any cold object (much more rapidly than air), it becomes moister; and, finally, when it has reached 212 degrees, any further cooling produces actual condensation of water on the lumber. In this respect it is a moist heating medium, but only as it cools. It is dry so long as it retains its superheat.

Explanation of Principles Involved

To understand the application of superheated steam to drying processes, it is necessary to comprehend certain underlying principles which are frequently overlooked or confused in the minds of those who are unfamiliar with the subject. These principles will be briefly discussed before presenting a description of the new Forest Service superheated steam kiln.

For simplicity, steam at atmospheric pressure only will be considered in this article. When steam has become saturated (212 degrees at atmospheric pressure) the only way in which it can impart heat to any object is by condensation. It is therefore incapable of producing evaporation in this

condition. Consequently, the only way it can be made to evaporate moisture from lumber is by superheating it, and as soon as it has cooled to 212 degrees again its usefulness for this purpose has departed.

While the heat-carrying capacity of superheated steam per pound of weight is greater than that of air (0.475 B. T. U. per degree of heat F. for steam and 0.237 for dry air) the weight per cubic foot is less, being only 0.6225 that of the air; therefore, by volume it requires nearly as much (0.8 as much as air) to impart the same amount of heat to the lumber and produce the same amount of evaporation. It must be remembered, however, that in the case of steam it completely ceases to produce evaporation when cooled to 212 degrees, whereas dry air can continue its function by cooling until it becomes saturated from the moisture evaporated.

For example, it will require 664 cubic feet of steam, heated to 320 degrees F. and cooled to 212 degrees, to evaporate one pound of water, or 3,657 cubic feet heated to 230 degrees to accomplish the same. Dry air heated to 212 degrees and cooling to 97 degrees and saturation will require 625 cubic feet. But 320 degrees temperature is altogether dangerous to the lumber.

It is evident, therefore, that in order to utilize superheated steam in lumber drying, either an excessive

temperature must be used, or else an enormous volume which means a high velocity.

There is yet another principle of prime importance, which must be taken into consideration. In the case of superheated steam the temperature throughout the pile must be above 212 degrees, otherwise no drying can take place and condensation even may occur. As superheated steam parts with its heat with exceeding rapidity in contact with a wet surface, it is impossible to maintain the required temperature through a large pile of lumber unless a very high velocity of steam exists, or a dangerous degree of superheating is used.

The novel features of the new Forest Service superheated steam dry kiln and those upon which its success depends, consist in the establishment of a very high and uniform velocity of steam through the pile of lumber, together with a complete periodical reversal of the direction of flow; thereby enabling a low initial degree of superheating to be used (225 or 235 degrees F.) and drying the pile of lumber clear through and equally from both directions.

Brief Description of Kilns

The kiln consists essentially of a closed chamber with well insulated walls, in which the lumber is flat piled lengthwise of the kiln, leaving a clear flue about one and a

half feet in width between the top of the pile and the roof and the bottom of the pile and the floor, and also a wide flue on either side of the pile. On the opposite side walls are hung the steam heating pipes, and near the four corners of the kiln and running its entire length are placed four steam jet pipes. These steam jets consist of perforations in the pipe placed every foot or so apart and pointed towards the opposite corner of the kiln, so that they will force the steam horizontally along the flues above and below the lumber pile. It will be noted that when the upper and lower series of jets on one side only of the kiln are turned on with high pressure steam the superheated steam will be forced through the layers of lumber in a direction contrary to that in which the jets are pointing. When these jets are turned off and the ones on the opposite side of the kiln are turned on, the circulation through the pile is directly reversed. Usually the current is reversed but once, after about half the time; but it may be done any number of times, the oftener the better.

The illustration shows a cross-section of a kiln of this kind. In the illustration, however, two piles of lumber, instead of one are shown, with an auxiliary row of heating pipes between. There is also an extra set of steam jets. B, C, D, and E are shields or baffles for better controlling the circulation of the superheated steam. A vent is placed at any

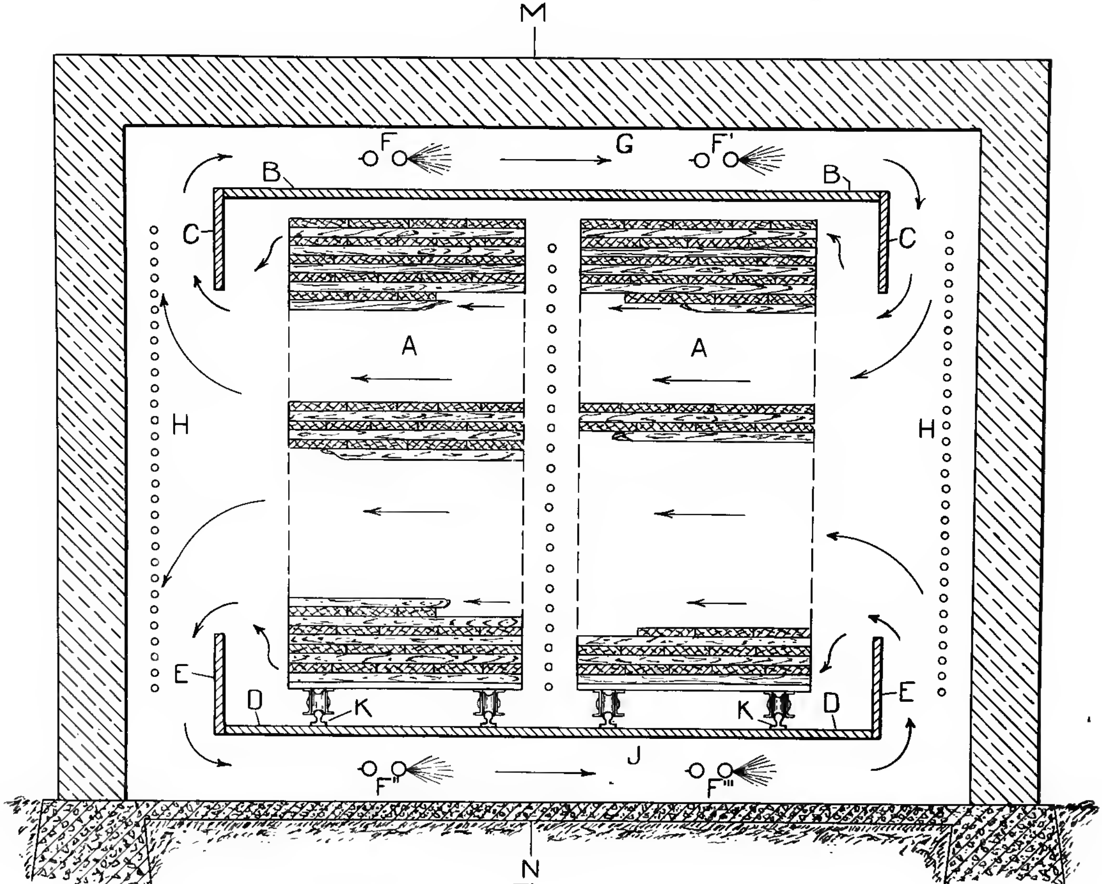

Fig. 1

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convenient place in the kiln to equalize pressure by allowing escape of excess steam.

Boiler pressure steam (at least 80-pound gauge) must be used for both the jets and the heating coils.

Application of the Process

This process will dry one-inch soft wood lumber from the green condition to less than 10 per cent in 24 hours or less. The consumption of steam, however, is greater per thousand of lumber dried than is the case with a well-designed ventilated progressive dry kiln, and it is recommended only where extreme economy in fuel is not needed. It is entirely unsuited for drying all hardwoods, and cannot be used for some softwoods on account of collapse. Where it is applicable, however, it appears to dry the lumber in better condition as to checking and warping than almost any other process, except very slow drying at high humidity and low temperature.

The temperature of the superheated steam as it enters the lumber should not exceed 230 degrees at the end of the run, but may be raised to 240 degrees while the lumber is still wet on the surface. The lumber should be run into the kiln directly from the saw with ~~as~~ little exposure or air drying as possible. It is deleterious for the lumber to be exposed to this temperature for more than two or three days; consequently it is

not advisable to attempt to dry lumber of thicknesses of more than two and one-half inches by this process. It should be stated, furthermore, that the treatment somewhat reduces the toughness of the lumber, so that where this quality is of prime consideration, as for airplanes and wagons, a low temperature process of drying should be used. On the other hand, it reduces the "working" of the boards and the hygroscopicity of the wood, as well as "fixing" resins and gums. The effect upon knots, as compared with low temperature drying, has not been fully determined, but apparently there is not much difference. A slight darkening of the sapwood occurs, increasing with the length of time of exposure, and for periods much over twenty-four hours the heartwood may darken also.

The process is applicable to the following species: Douglas fir; firs, all kinds; western hemlock (not eastern); white cedars (not western red); sugar pine (some brown stain); western yellow pine; southern yellow pine (slight darkening of sapwood).

One-inch longleaf pine has been dried commercially from 5,000 pounds to 3,400 pounds per thousand (61 per cent to 10 per cent moisture) in twenty-four hours, with a consumption of 4,500 pounds of steam per thousand.

Douglas fir has been dried from 32 per cent to 9 per cent moisture in from twenty-two to twenty-four hours. The steam consumption is estimated as 3,300 pounds per thousand.

For further information the Forest Products Laboratory at Madison, Wis., should be consulted.

Patent No. 1268180, June 4, 1918, H. D. Tiemann, dedicated to the Government.

U. S. Department of Agriculture, Forest Service
FOREST PRODUCTS LABORATORY
In cooperation with the University of Wisconsin

MADISON, WISCONSIN

BRAIN WORK IN KILN OPERATION

By C. V. SWEET
Specialist in Kiln Drying

Approved Copy Filed

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BRAIN WORK IN KILN OPERATION

C. V. Sweet
Specialist in Kiln Drying

There is no phase of kiln drying that stands out more clearly as essential to success or directly responsible for failure than the intelligence and attention that is given to the operation of the kiln. Those who have watched with particular interest the progress of the practice of kiln drying lumber especially under the stress of war conditions, have seen that the greatest difference between success and failure has been in the operation more than in the kilns themselves, whether it has been with airplane stock, green oak vehicle stock, ship timbers, or wooden legs. Poor kilns and good operation have often produced as good results, as good kilns and poor operation. But in the long run, the big problems of artificially seasoning lumber will be solved only by a happy combination of the two factors. It takes a good kiln and good operation to obtain really good results.

It has frequently been brought to the attention of the Forest Products Laboratory of the United States Forest Service at Madison, Wisconsin, that with a given type of dry kiln, handling similar kinds of stock according to the same recommended schedule, one concern has dried its material with practically no loss while another suffered a loss of 40 to 50 per cent.

If the art of kiln drying lumber has come through its recent trials trimmed of some non-essential ideas and benefited by new conceptions, the sum total of our information concerning it has been greatly increased. On the other hand, if there is still a vestige of the old notion that "this kind of kiln will dry lumber in half the time and less checking than that kind of kiln", a big load of inertia must still be moved.

Emphasis on the operation of the dry kiln means the injection of the human, intelligent, interested element into kiln drying which is too frequently absent in the methods of many concerns. The kind of kiln operation that is possible at the hands of an ex-lumber piler who has become too old to work efficiently anywhere else, or of a man who has grown up with the company and in his later years deserves an easy job, or of, a fireman at the plant who has a few extra hours to fill in - that kind of kiln operation does not enter into this consideration.

The kiln drying of lumber, unless it be the drying of air seasoned soft woods, is an art involving special knowledge, skill and good workmanship. Without detracting from the credit of the practical lumbermen, it may be said that the greatest advances in kiln drying have come in the last few years. This advance, reflected in new methods of seasoning, is the outgrowth of accumulated scientific knowledge of the physical

and mechanical properties of wood. The successful dry kiln operator today has to think of characteristics of wood in terms which are unfamiliar and in many instances distasteful to the older type of practical lumberman.

As a matter of fact this conception of the role of operation in kiln drying is opposed to a more or less general commercial tendency to make kiln drying an automatic process from which the element of personal judgment is removed as much as possible, thereby attributing to dry kilns in themselves whether of one particular design or another some mystic, secret capacity to dry lumber perfectly with the minimum watching by a competent operator. Or often lumber is supposed to be dried successfully by some socalled "patented process". Sad experienc shows that it is impossible to put lumber in a dry kiln like a potato in an oven and take it out all done to a queen's taste.

It is not uncommon to read in advertisements in trade journals that this or that kind of dry kiln or process dries lumber without checking, honey-combing, or casehardening. Such a statement is the danger signal. A simple statement that temperature and humidity conditions are flexible and under the immediate control of the operator would inspire more confidence.

The most satisfactory types of kilns yet developed are those with features of automatic temperature and humidity control which make the operator a complete master of his kilns

in that any conditions which he regards beneficial to the lumber may be maintained hour after hour, or day after day, until he considers it desirable to change such conditions.

The kiln operation itself can never become automatic although the control of drying conditions may well be that, and efforts to bring about automatic control of such phases are most decidedly on the right track. A brief and general discussion of some of the features of kiln operation which are of utmost importance may throw additional light on the importance of the skilled operator as apart from the kiln.

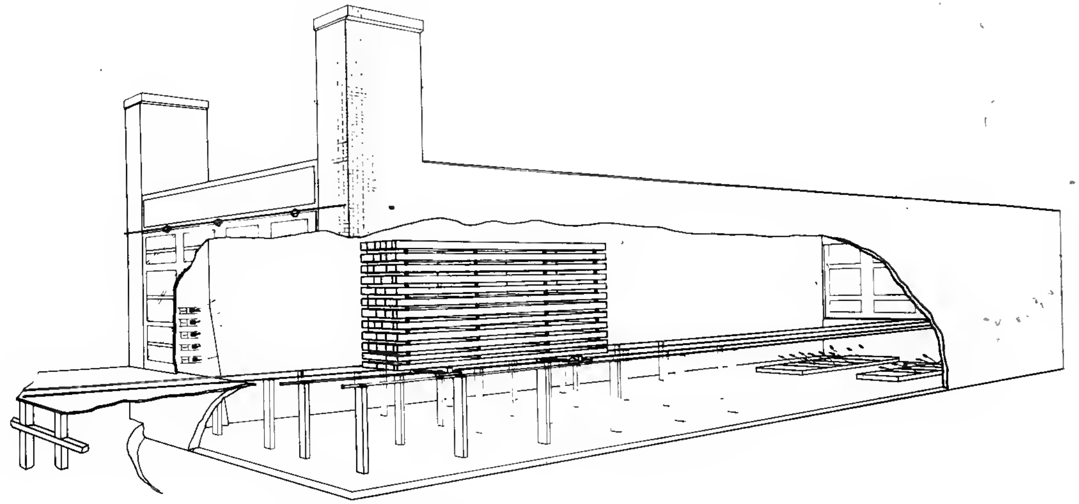
Relation Between Method of Piling And Uniformity of Drying

The first opportunity for an exhibition of skill in kiln operation is in the adoption of the proper system of piling the lumber in the kiln. It may be safely said that comparatively few kilns are operated with any thought as to whether the piling suits the kiln or not. Because of the very definite relation that exists between method of piling and the circulation of air in the kiln, this subject is to be as strongly emphasized as careful temperature control and regulation of the humidity.

First and foremost, lumber is piled in the dry kiln so as to dry uniformly and as quickly as possible. There is no more effective way of bottling up the circulation in a kiln and slowing up the drying rate than by piling in lumber across the path of the moving air. The piling should be such as to offer the least obstruction to a free and positive circulation of air within the kiln. Methods of piling which lead to complete utilization of all space and in greatest economy of handling the lumber through the kiln are important features to be sure, but entirely secondary and subordinate to the method that conforms to the circulation system of the kiln. The method of piling must be such as will throw the "stickers" parallel to the predominant air currents and never perpendicular to and obstructing it. circulation parallel to faces of boards.

End piling in a progressive type of kiln, which depends for its circulation on the passage of air from the hot, dry end to the green, cool end places great obstruction to free and uniform passage of air and is obviously wrong. Cross piling in a type of kiln in which the circulation is vertical - lateral as in many types of ventilated and condenser kilns is just as serious in that the normal air currents are obstructed.

This point is illustrated clearly by a case of practical experience. Some 4/4 green maple was loaded into a dry kiln having vertical-lateral circulation. Part of the stock was end piled and part of it cross piled. Temperature readings were taken daily at different parts of both piles. After the run was well started the difference between the hottest and coolest portion of the end piled stock was 10° while the difference in the cross piled stock was 58°. This had a marked effect on the uniformity of drying. The end piled stock dried from 30 per cent to a maximum moisture content of 6 per cent in 10 days while it took 13 days for the stock piled crosswise to dry from 30 per cent down to 12 per cent. This shows that there is a right and wrong way for lumber to be piled in every type of kiln.



LUMBER PILED ENDWISE IN AN INSTALLATION OF PROGRESSIVE KILNS AT A FURNITURE PLANT IN OHIO

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Madison, Wis.
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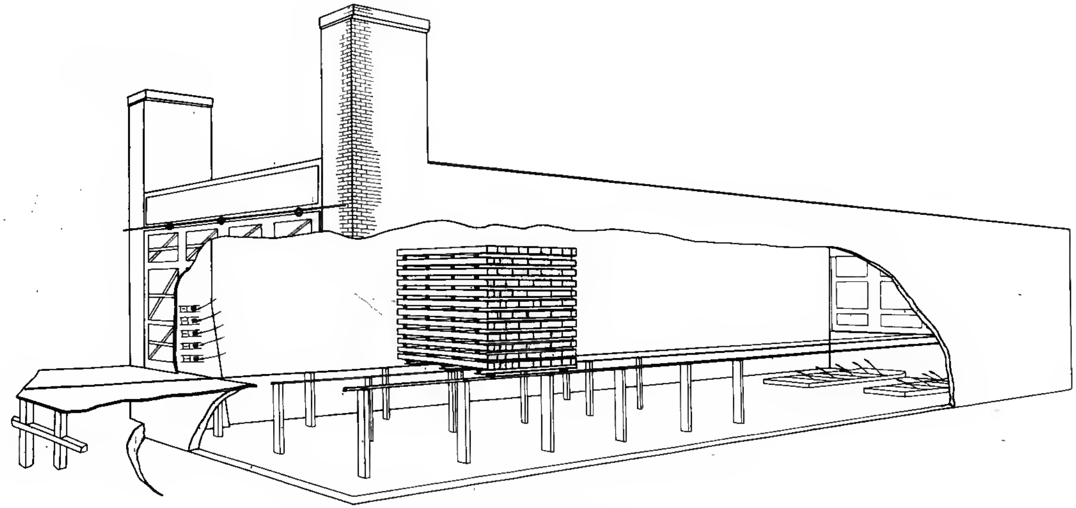
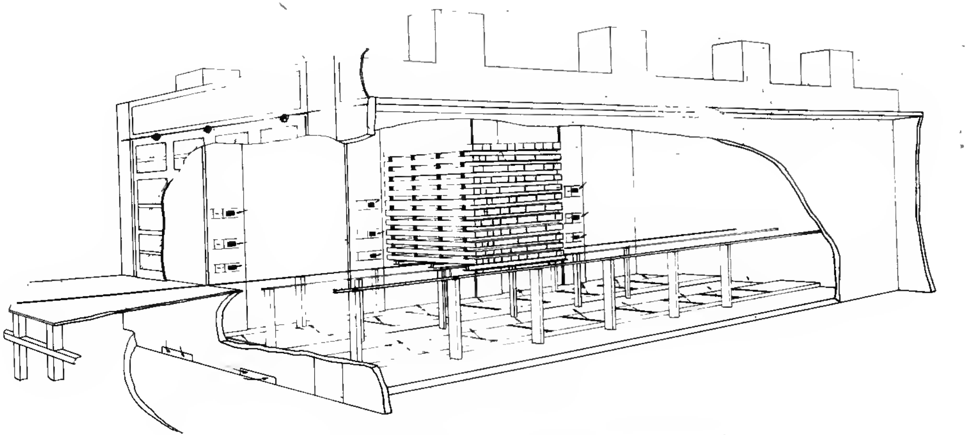


LUMBER PILED CROSSWISE IN AN INSTALLATION OF SIMILIAR KILNS AT A FURNITURE PLANT IN NEW YORK STATE

Sketches of representative commercial installations of a type of progressive kiln in which the circulation of air is from end to end. Note that in end piling the "stickers" oppose and obstruct the intended circulation.

Both end and cross piling are often used in this type of kiln, but cross piling is distinctly superior to end piling, from the standpoint of circulation. This illustrates the lack of attention to a very important item of kiln drying.



LUMBER PILED CROSSWISE IN AN INSTALLATION OF COMPARTMENT KILNS AT A FURNITURE PLANT IN PENNSYLVANIA

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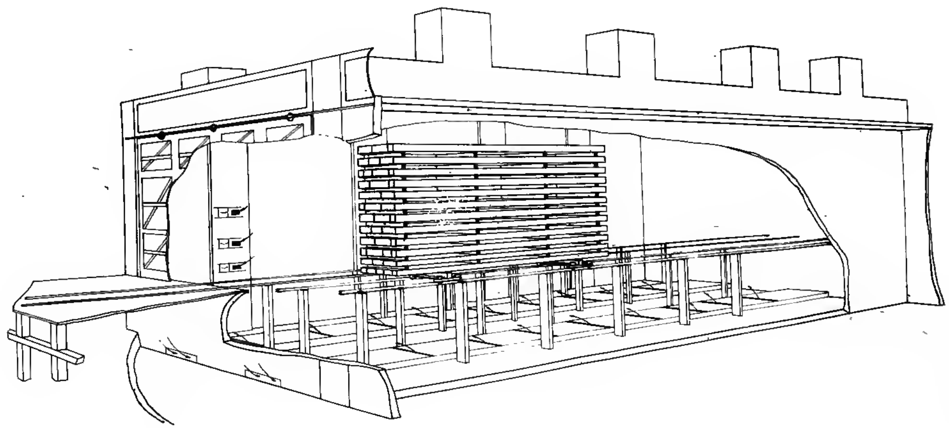


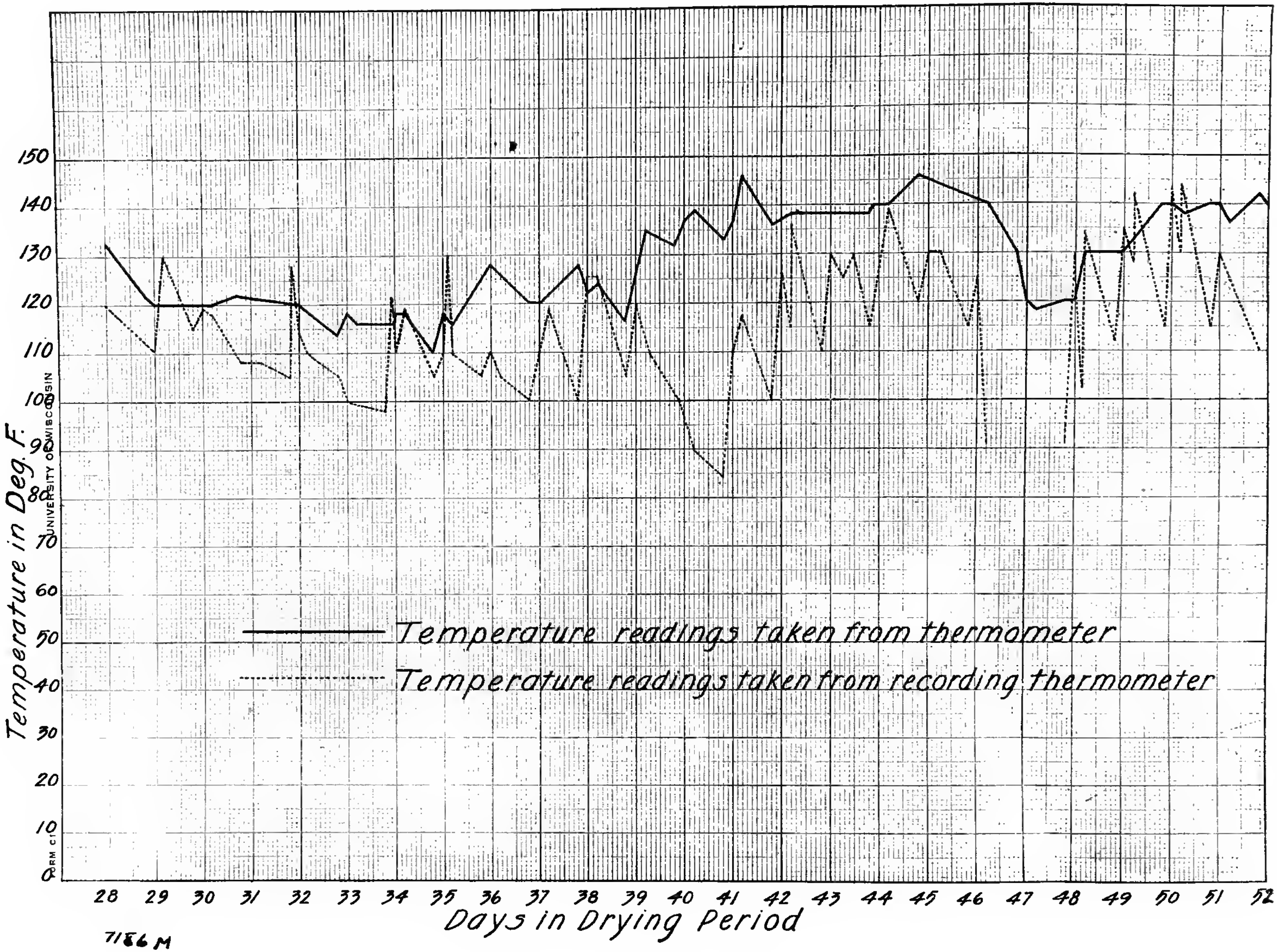
LUMBER PILED ENDWISE IN AN INSTALLATION OF SIMILIAR KILNS AT A FURNITURE PLANT IN MICHIGAN

Sketches of representative commercial installations of a type of compartment kiln in which the circulation of air is up in the center and down and out at the sides. Cross piling places greatest obstruction to this system of circulation. At one plant the lumber is piled crosswise and at the other is piled endwise. There is only one of the two methods which can be right. Another illustration of failure to give attention to circulation in the kiln.

To those interested in even, rapid drying, this point is of great practical significance.

Knowledge of Actual Conditions in Kiln Prevents Losses in Stock

After the lumber is properly piled in the kiln and the heat turned on the competency of the operator again comes into play. It is essential that the operator know accurately the drying conditions in every part of the kiln. The determination of the conditions to which the lumber is actually subjected is a critical phase of kiln operation. With that knowledge available to the operator no lumber need be ruined in any dry kiln. If one part of the kiln is warmer than another, that fact should be known by the operator and allowances made therefore. If one end of the kiln runs at lower humidity than the other, that fact should be known and reckoned with. When measurements of temperature and humidity are taken they are too often taken by sticking an instrument through a hole in the big door and assuming that all parts of the kiln read the same as near the door. The temperature and humidity taken at any one part of the kiln are no criterion of the condition in other parts of the kiln unless the circulation is more perfect than in most kilns.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Days in Drying Period
Temperature readings taken from thermometer
Temperature readings taken from recording thermometer

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An actual record of temperature conditions during the kiln drying of heavy, green oak at an auto body plant in Ohio. Note the great difference in temperature readings obtained from the recording instrument in one part of the kiln and from a standard thermometer in another part. The operator of the kiln did not know under what condition the lumber was actually being dried. Result was loss of 70 per cent.

The kiln operator should know the behavior of his kiln when lumber is being dried in it as an engineer knows the correlated workings of his gas engine.

Regulation of Kiln Should be Based Entirely on Moisture Condition of Lumber

The fundamental basis of kiln regulation is the actual condition of the lumber in the kiln. This statement ought to be as easily and broadly recognized by kiln operators as the fact that the amount of fire under a boiler is the measure of the amount of heat produced, and yet there is a most flagrant disregard of this fundamental truth in many kiln drying operations. Ordinary practice involves kiln operation based on the number of days that the lumber has been in the kiln. The variation in the original condition of the lumber is so great, the difference in the drying conditions in the kiln are so pronounced that this method is uncertain. This practice when applied to the commercial drying of heavy green oak has resulted in exorbitant losses

The whole dry kilning operation is linked up with the amount of moisture in wood and obviously the operation of the kiln must be on that basis.

It is a well established fact that there is a point in the drying process around which the entire drying schedule

should center. It is the point which marks the dividing line between green and partially seasoned wood. Up to this point the drying condition must be moderate and constant and after which the drying may take place more rapidly. Technically this point in the drying is called the Fiber Saturation Point and practically it corresponds roughly to moisture content of 25 per cent based on the bone dry weight of the wood.

There is no way of knowing when the lumber in the kiln is ready to stand higher temperature except by knowing how much moisture there is left in the wood. The number of days that the lumber has been in the kiln is of slight importance and no significance in this connection.

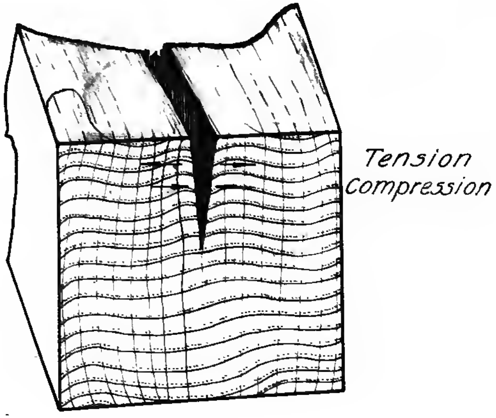
The one criterion of regulation is the moisture content of the lumber and its fitness to withstand more severe drying conditions and never the number of days that the lumber has been in the kiln.

It Pays to Watch Behavior of Lumber During Kiln Drying

Brain work in connection with kiln operation shows up more than anywhere else in watching the effect of the drying on the condition of the stock itself. To go into a warm moist kiln especially on a hot summer day and look for surface checks and other defects is not the most agreeable thing in the world but it is worth while when a kiln load of expensive lumber is at stake. In the old-time kiln operation to spend any time in the dry kiln was never thought of, in fact, in most kilns there is no way to get into the kiln except the main door be opened thereby letting out the heat and exposing the lumber.

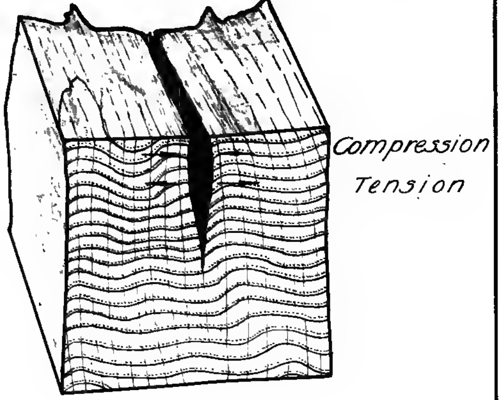
A furniture man when consulted regarding his troubles in kiln drying green oak was urged to cut a small door in the large kiln door so that the operator could get in easily to watch the condition of the stock from day to day. His contention in opposition was that a small door was a nuisance; that it was continuously getting out of repair and that it so weakened the big door that it would go to pieces in 2 or 3 years. The stock in his dry kiln cost him around $1000, he could have built a new kiln door, when the old one was too weak, for $100, but the lumber in the kiln according to this business man's reasoning was not worth the kiln door. It is a matter of record that his $100 worth of oak was a total loss, but that his kiln door is still in good condition.

What are some of the things that can be seen by watching the stock? And the answer is -- Practically all of the things that result in losses of lumber during kiln drying. Symptoms can be seen and they can be fought just as a physician fights the symptoms of disease. If the temperature in the kiln is too high and the lumber too green, the stock checks and casehardens. Maybe the class of work is such that a few surface checks do not count. Maybe the operator knows that the checks will close during the remainder of the drying. What closes these surface checks? Usually a compression on the surface and a tension on the inside which is called casehardening. And the force which is powerful enough to close these surface checks is also powerful enough to cause an internal rupturing of the fibers or honeycombing, which happens when the condition is allowed to continue. When checks under the force of this tremendous compression strain begin to develop concave sides upon continued drying and begin to "pinch in" at the surface - the danger sign is out. The operator must be there to see the sign.



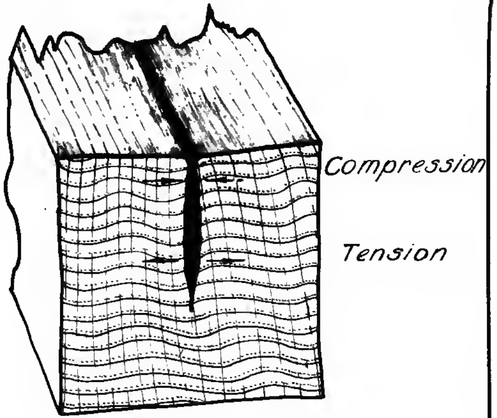
I

A slight surface check has developed into a deep check because of too rapid drying from the surface.
At this stage the outside is in tension



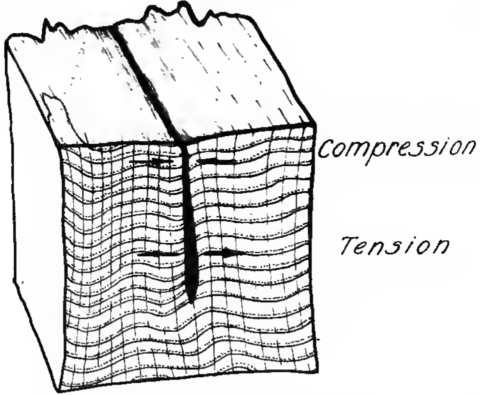
II

Surface check begins to close as drying continues due to the compression that has been set up on the outside opposing the tension on the inside. Early stage of casehardening.



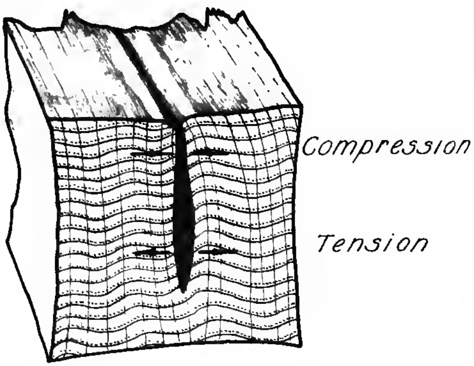
III

Surface check nearly closed as drying proceeds still farther and casehardening increases.



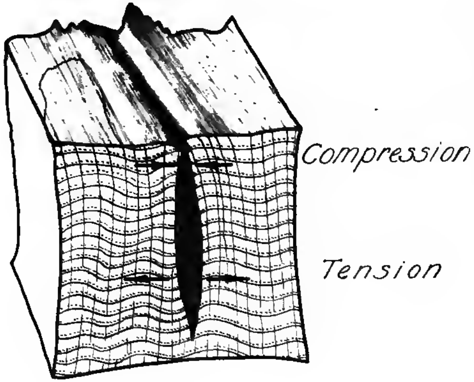
IV

Surface check entirely closed by the force of compression on outer surfaces, compression continues to increase even after check is closed at surface and causes the "pinching in" of the check.
This is the time to steam to relieve casehardening.



V

"Pinching in" becomes more severe due to increasing force of compression on outside due to severe casehardening.



VI

Final stage of honeycombing resulting from improper closure of surface check Note the off-set along the grain, Which is a surface condition of honeycombing

Forest Prod Laboratory
Forest Service

Stages in the development of honey-combing from a surface check which has developed early in the drying and allowed to close up without proper steaming treatment in the dry kiln. The application of steam at the proper time prevents honey-combing.

The sketches above are to be regarded as imaginary cross-sections cut through the same check during successive stages in the drying.

Wise Steaming Is Both a Pound of Prevention and Ounce of Cure

The remedy to be applied to lumber which shows defects and danger signs during drying is a comparatively recent one, not completely understood, but of broad application and great value. It consists of the application of saturated steam for a period of time and at a temperature which in the judgment of the operator suits the case at hand. The application of this curative principle must be understood before applied because, like most effective treatments, it can work detriment as well as benefit.

This principle may be used at the beginning of the run to heat the lumber through to the center before drying from the outside begins, also in the case of partially seasoned stock to relieve the tendencies toward casehardening which have been set up during air drying. As such it is often called preliminary steaming. A steaming or sweating of this nature is usually for a period of about 6 hours per every inch in thickness and at a temperature of only about 25° higher than the temperature at which the run is to start. The practice of steaming for a period of several days at the start is a big waste of drying time; does not accomplish more than can be accomplished in a few hours and actually damages the stock.

To kill mold that develops on the lumber in the kiln when the drying conditions are mild an application of saturated steam for an hour at a temperature of 165-180 degrees is most effective.

The most valuable application of the remedy is to lumber which has become casehardened to the extent that the wood fibers tend to give way to the stresses set up or when the surface checks show indications of "pinching in". It is necessary to steam at a temperature of 160-180 degrees for a period of one to several hours depending on the severity of the case as judged by the operator. This saturated steaming at high temperature moistens the outside of the wood and reduces the stresses and the hard bony surfaces that have been set up in the wood fibers. With these stresses removed, the danger of honeycombing is gone and the drying may continue according to schedule until perhaps the stresses become serious again necessitating another application of steam. When the lumber is ready to be removed from the kiln and it is severely casehardened with the tendency to warp after machining in the shops and upon resawing, proper application of saturated steam removes the casehardening set up and greatly improves the quality of the material.

Operation of Kiln Most Important Element in Kiln Drying

Operation means knowing the exact temperature and humidity at which the lumber is actually drying all over the kiln, it means knowing how the wood is reacting to the conditions as told by symptoms such as checking, casehardening and moisture distribution.

When these things are appreciated and known accurately, the art of kiln drying lumber will have taken a step forward and more general commercial success will be realized.

U. S. Department of Agriculture, Forest Service

FOREST PRODUCTS LABORATORY

In cooperation with the University of Wisconsin

MADISON, WISCONSIN

List of publications on

WOOD PRESERVATION

May, 1921

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LIST OF GOVERNMENT
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One circle (°) appearing before the title of a bulletin or circular indicates that the supply available for distribution from this laboratory is exhausted, but that it may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., for the price indicated.

One circle (°) appearing before the title of a journal article indicates that the supply available for distribution from this laboratory is exhausted and that it will have to be consulted in the original publication.

Two circles (°°) appearing before the title of a government bulletin or circular indicate that it is out of print.

Technical notes are published by this laboratory and may be obtained free upon application.

LIST OF GOVERNMENT
PUBLICATIONS ON WOOD PRESERVATION

Crossties

Bulletins and Circulars

°°Division of Forestry Bulletin 9 - Report on the Use of Metal Railroad Ties and on Preservative Processes and Metal Tie-Plates for Wooden Ties.

°°Forest Service Bulletin 50 - Crosstie Forms and Rail Fastenings with Special Reference to Treated Timbers - 1904.

°Forest Service Bulletin 51 - Report on Condition of Treated Timbers Laid in Texas, February, 1902 - 1904; 10 cents.

Forest Service Bulletin 118 - Prolonging the Life of Cross-Ties - 1912 - 15 cents.

°Forest Service Bulletin 126 - Experiments in the Preservative Treatment of Red Oak and Hard Maple Crossties - 1913 - 20 cents.

°Forest Service Circular 46 - Holding Force of Railroad Spikes in Wooden Ties - 1906 - 5 cents.

°Forest Service Circular 132 - The Seasoning and Preservative Treatment of Hemlock and Tamarack Crossties - 1908 - 5 cents.

°Forest Service Circular 146 - Experiments with Railway Cross-Ties - 1908 - 5 cents.

°°Forest Service Circular 209 - Service Tests of Ties - 1912 - 5 cents.

Crossties (Cont.)

Journal Articles

°The apparent relation between rainfall and durability of zinc-treated ties, - Teesdale and Allen - American Wood Preservers Association, 1919.

°Service tests of crossties - Hicks - American Wood Preservers Association, 1917, pp. 85 - 228, and American Railway Engineering Association, 1917, pp. 1291-1435.

Relation between average life of ties and per cent of renewals - Thorne - Railway Review Jan. 26, 1918, and American Wood Preservers Association, 1918.

°Grouping of ties for treatment - Winslow - Railway Review, Jan. 27, 1917, and American Wood Preservers Association, 1917.

°Service tests of crossties - Teesdale and Winslow - American Wood Preservers Association, 1916, pp. 265-330.

°Service tests of crossties - Hicks - American Wood Preservers Association, 1917, and American Railway Engineering Association, 1917.

°Service tests of crossties - Hicks - American Railway Engineering Association, 1918.

°Service tests of ties in the C. & N. W. Ry; near Janesville, Wis.; N. P. Ry., near Plains, Mont.; and N. P. Ry., near Maywood, Wash. - Teesdale - American Railway Engineering Association, March, 1916, p. 463.

°Tie durability records - Winslow and Teesdale - American Railway Engineering Association, March, 1916, p. 463.

°Some factors affecting the application of wood preservation to electric railways - Winslow and Teesdale - American Railway Engineering Association, 1915.

°Recent progress in testing wood used by the railroads - Weiss - Proc. St. Louis Ry. Club, May 12, 1916,pp.21-29.

Crossties (Cont.)

Journal Articles (Cont.)

°The protection of ties from mechanical destruction - Weiss - American Wood Preservers Association, 1914, pp. 249-260 and Hardwood Record, Feb. 10, 1914.

°The transmission of air pressure in crossties - Winslow, American Wood Preservers Association, 1913, pp. 288 - 316.

°A comparison of zinc chloride with coal-tar creosote for preserving crossties - Weiss - American Wood Preservers Association, 1913, pp. 81-83.

°The effect of varying the preliminary air pressure in treating ties upon the absorption and penetration of creosote - Teesdale - American Wood Preservers Association, 1914, pp. 323-351.

The properties of western tie woods - Hicks - Railway Maintenance Engineer, December, 1920.

Durability of western tie timber - Hicks - Railway Maintenance Engineer, March, 1921; also summarized in Railway Age, April 22, 1921.

Mimeographed articles

Treating ties by the open tank process.

Technical Notes

F-15	Effect of Time of Cutting Timber on Its Durability.
F-33	Durability of Green and Seasoned Timber.
87	Relative durability of Rocky Mountain and Pacific Coast Douglas fir ties.
113	Color of cypress heartwood no indication of durability.
130	Tie renewals in relation to average life.

Decay

Bulletins and Circulars

°Department of Agriculture Bulletin 510 - Timber storage conditions in the eastern and southern states with reference to decay problems - 1917 - 20 cents.

°Bureau of Plant Industry Bulletin 14 - The decay of timber and methods of preventing it - 1902.

Journal Articles

°Rot in stored lumber - Humphrey - American Lumberman, Aug. 14, 1915, pp. 32-33.

°Decay an important factor in plant management - Hunt - Wood Preserving, April, 1916 - pp. 30-31.

°Protecting wood from decay and fire - Teesdale - Scientific American, Oct. 20, 1917.

Decay in wooden bleachers - Teesdale. Engineering Record, Oct. 3, 1914, and American Lumberman, Oct. 3,1914.

Mimeographed Articles

List of references to literature on the decay of wood.

Technical Notes

A-1 Hints on storing lumber to prevent decay.
105 What is dry rot?
133 Difference between molds and wood destroyers.

Effect of Treatment on Strength

Bulletins and Circulars

Department of Agriculture Bulletin 286 - Strength tests of structural timbers treated by commercial wood preserving processes - 1915 - 5 cents.

ooForest Service Circular 39 - Experiments on the strength of treated timber - 1908 - 5 cents.

Journal Articles

oStrength tests of structural timbers treated by commercial wood preserving processes - Betts and Newlin - Railway Review, Feb. 19, 1916.

oResults of some tests of the effect of zinc chloride on the strength of wood - Wilson and Bateman - American Wood Preservers Association, 1921.

Mimeographed Articles

List of some references on the effect of preservative treatment on the strength of timber.

Fireproofing

Journal Articles

[1]Tests on the inflammability of untreated wood and of wood treated with fire retarding compounds - Prince; Proc. National Fire Protection Ass'n., 1915, pp. 108-157.

oFireproofing wooden shingles - Weiss; American Roofer, December, 1915.

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[1] May be obtained from the secretary of the association, 87 Milk Street, Boston, Mass., for 25 cents.

Fireproofing (Cont.)

Journal Articles (Cont.)

°Preliminary work in fireproofing wood - Prince - American Wood Preservers Association, 1914, pp. 158-172.

°Protecting wood from decay and fire - Teesdale - Scientific American, Oct. 20, 1917.

Mimeographed Articles

Fireproofing of wood.

Technical Notes

106 Making wood fire resistant with paint.

Mine Timbers

Bulletins and Circulars

°Department of Agriculture Bulletin 77 - Rocky Mountain mine timbers - 1914 - 5 cents.

°°Forest Service Bulletin 107 - The preservation of mine timbers - 1912 - 10 cents.

°°Forest Service Circular 111 - Prolonging the life of mine timbers - 1907 - 5 cents.

Technical Notes

110 Saving mine timbers from decay.

Piling and Marine Borers

Bulletins and Circulars

°Forest Service Circular 128 - Preservation of piling against marine borers - 1908 - 5 cents.

°°Forest Service Circular 199 - Quantity and quality of creosote found in two treated piles after long service - 1912.

Journal Articles

Study of wood preservatives and marine borers - Teesdale and Shackell - Railway Age Gazette, Nov.2,1917.

°Marine wood borers - Teesdale - Scientific American Supplement, Dec. 5. 1914.

°Saving of creosote oil in the treatment of piling - Teesdale - Wood Preserving, October, 1915.

°Efficiency of various parts of coal-tar creosote against marine borers - Teesdale - Engineering Record, Sept. 12, 1914.

°Calculating the volume of poles and piles - Hunt - American Wood Preservers Association, 1917.

°Report of San Francisco Bay Piling Committee - American Wood Preservers Association, 1921.

Mimeographed Articles

Durability of treated and untreated piling above mean low water.
List of books and papers relating to marine wood borers.

Technical Notes

F-20 Durability of untreated piling above low tide.
F-21 Calculating the volume of poles and piles.
86 Some references to publications on marine borers.
96 Resistance of greenheart to various marine borers.

Poles and Posts

Bulletins and Circulars

^{o}Forest Service Bulletin 84 - Preservative treatment of poles - 1911 - 15 cents.

Farmers' Bulletin 744 - The preservative treatment of farm timbers - 1916.

^{oo}Forest Service Circular 104 - Brush and tank pole treatments - 1907.

^{oo}Forest Service Circular 117 - The preservative treatment of fence posts - 1907 - 5 cents.

^{oo}Forest Service Circular 151 - Preservative treatment of loblolly pine crossties - 1908.

Forest Service Circular 198 - Condition of experimental chestnut poles in the Warren-Buffalo and Poughkeepsie-Newton Square lines after five and eight years' service - 1912 - 5 cents.

^{o}Department of Agriculture Bulletin 67 - Tests of Rocky Mountain woods for telephone poles (strength tests) - 5 cents.

^{oo}Forest Service Circular 101 - The open tank method for the treatment of timber - 1907.

^{oo}Forest Service Circular 103 - Seasoning of Telephone and Telegraph poles - 1907.

^{oo}Forest Service Circular 136 - The seasoning and preservative treatment of arborvitae poles - 1908.

^{oo}Forest Service Circular 147 - Progress in Chestnut pole preservation - 1908.

Journal Articles

^{o}Calculating the volume of poles and piles - Hunt - American Wood Preservers Association, 1917.

Poles and Posts (Cont.)

Journal Articles (Cont.)

Service tests of treated and untreated fence posts - Bradley - American Railway Engineering Association Bulletin 187, July, 1916.

°Service tests of posts and poles - Hicks; American Wood Preservers Association, 1917.

°The Preservative treatment of farm timbers - Hunt; Wood Preserving, October, 1915.

°Service tests of treated and untreated telephone poles - Teesdale; Telephony, April 3, 1915.

Condition of experimental poles in the Augusta-Savannah and Helena-Meldrim lines - Teesdale; Engineering News, Nov. 27, 1913.

°Service tests of treated and untreated poles - Hicks; National Electric Light Association Bulletin - 1921.

°Experiments with butt-treated poles in California - Hicks; American Wood Preservers Association, 1921, and Electric Railway Journal, Feb.26,1921, p.400.

Service tests of treated and untreated fence posts - MacLean - American Wood Preservers Association,1921.

Mimeographed Articles

Results of some strength tests on wooden poles.
Durability of treated and untreated posts and poles.
Statement to accompany table of "Results of Tests on Poles".

Technical Notes

A-1 Hints on Storing Lumber to Prevent Decay.
F-15 Effect of Time of Cutting Timber on Its Durability.
F-21 Calculating the volume of poles and piles.

Poles and Posts (Cont.)

Technical Notes (Cont.)

F-33 Comparative Durability of Green and Seasoned Timber.
108 Charring Does Not Preserve Wood.
113 Color of Cypress Heartwood No Indication of Durability.
135 Split Posts and Round Posts.

Preservatives

General

Bulletins and Circulars

Department of Agriculture Bulletin 145 - Tests of wood preservatives - 1915; 10 cents.

°°Forest Service Circular 186 - Consumption of wood preservatives and quantity of wood treated in 1910 - 1911.

Department of Agriculture Bulletin 227 - The toxicity of various oils and salts to fungi - 1915; 10 cents.

Journal Articles

°Tests to determine the commercial value of wood preservatives - Weiss; 8th International Congress of Applied Chemistry, 1912, and Journal Industrial and Engineering Chemistry, Volume 5, No. 5.

°Toxicity of various wood preservatives I, II, - Humphrey and Fleming - Journal Industrial & Engineering Chemistry, Feb., 1914, and August, 1915.

Quantity of wood preservatives consumed and amount of wood treated in the United States in 1915 - Helphenstine; American Wood Preservers Association, 1916.

Ditto - 1916 - Helphenstine - American Wood Preservers Association, 1917.

Preservatives (Cont.)

Journal Articles (Cont.)

°Quantity of wood preservatives consumed and amount of wood treated in the United States in 1917 - Helphenstine - American Wood Preservers Association, 1918.

°Ditto - 1918 - Helphenstine - American Wood Preservers Association, 1919.

Ditto - 1919 - Helphenstine - American Wood Preservers Association, 1920.

Ditto - 1920 - Helphenstine - American Wood Preservers Association, 1921.

Mimeographs

Specifications for creosote oil for brush and open-tank treatment.
Specifications for creosote oil for ties and structural timber, Grades 1, 2, and 3.
Specifications for creosote coal-tar solution for ties and structural timber.
Specifications for coal-tar creosote for marine work.
Specifications for zinc chloride.
Specifications for preservatives for paving blocks.

Technical Notes

114 Water solubility a necessary property of wood preservatives.
118 Loss of creosote by evaporation from open-tanks.

Preservatives (Cont.)

Coal-Tar Creosote

Bulletins and Circulars

Department of Agriculture Bulletin 101 - Relative resistance of various conifers to injection with creosote - 1914 - 15 cents.

Department of Agriculture Bulletin 606 - Relative resistance of various hardwoods to injection with creosote - 1918 - 15 cents.

Department of Agriculture Bulletin 607 - Absorption and penetration of tar and creosote in longleaf pine -- 1918 - 15 cents.

°°Forest Service Circular 80 - The fractional distillation of coal-tar creosote - 1907.

°Forest Service Circular 98 - Quantity and character of creosote in well preserved timbers - 1907 - 5 cents.

°°Forest Service Circular 112 - The analysis and grading of creosotes - 1908.

°Forest Service Circular 188 - Volatilization of various fractions of creosote after their injection into wood -- 1911 - 5 cents.

°°Forest Service Circular 191 - Modification of sulphonation test for creosote - 1911 - 5 cents.

°°Forest Service Circular 199 - Quantity and quality of creosote found in two treated piles after long service - 1912.

°Forest Service Circular 200 - The absorption of creosote by the cell walls of wood - 1912 - 5 cents.

°°Forest Service Circular 206 - Commercial creosotes -- 1912 - 10 cents.

Preservatives (Cont.)

Coal Tar Creosote (Cont.)

Journal Articles

°Effect of soaking and subsequent air seasoning of Douglas fir upon absorption and penetration of creosote - Hunt; Wood Preserving, Oct.-Dec., 1917.

°The relation between the toxicity and the volatility of creosote oil - Bateman; Journal of Industrial and Engineering Chemistry, Dec., 1916; and Wood Preserving, Oct. - Dec., 1916.

°The application of the Davis spot test in the preliminary examination of creosotes - Cloukey - Journal of Industrial and Engineering Chemistry, Nov., 1915.

°Saving of creosote oil in the treatment of piling - Teesdale - Wood Preserving, Oct., 1915.

°Efficiency of various parts of coal-tar creosote against marine borers - Teesdale; Engineering Record, Sept. 12, 1914.

°The effect of varying the preliminary air pressure in treating ties upon the absorption and penetration of creosote - Teesdale - American Wood Preservers Association, 1914, pp. 323 - 351.

°A comparison of zinc chloride with coal-tar creosote for preserving crossties - Weiss; American Wood Preservers Association, 1913, pp. 81 - 83.

°Some tests to determine the effect upon absorption and penetration of mixing tar with creosote - Bond; American Wood Preservers Association, 1913, pp.216-274.

°What light creosote oils have done in wood preservation - Bateman; American Wood Preservers Association, 1920.

Relation between viscosity and penetrance of creosote into wood - Bateman; Chemical and Metallurgical Engineering, Feb. 25, 1920.

Preservatives (Cont.)

Coal Tar Creosote (Cont.)

Journal Articles (Cont.)

The isolation of barren oil from coal-tar creosote and a mathematical proof of the existence of a solubility partition - Bateman; American Wood Preservers Association, 1921.

Mimeographs

Specifications for creosote oil for brush and open-tank treatment.
Specifications for creosote oil for ties and structural timbers, Grades 1, 2, and 3.
Specifications for creosote coal-tar solution for ties and structural timbers.
List of creosote producers and dealers in the United States.
List of foreign manufacturers of creosote.
Report on laboratory experiments to determine loss of creosote by evaporation from open-tank treatments.

Technical Notes

100 Light creosote oils in wood preservation.
118 Loss of creosote by evaporation from open tanks.

Sodium Fluoride

Journal Articles

Use of fluorides in wood preservation - Teesdale; Wood Preserving - Oct. 1916, and Jan. 1917.

Will sodium fluoride come into general use for preserving wood.

Preservatives (Cont.)

Sodium Fluoride (Cont.)

Mimeographed Articles

Preservation of timber by the steeping process.
List of manufacturers of sodium fluoride.

Technical Notes

F-34 Sodium fluoride as a wood preservative.
110 Saving mine timbers from decay.

Water-Gas Tar and Water-Gas-Tar Creosote

Journal Articles

°Some recent results on water-gas tar and creosote as a wood preservative - Teesdale; Engineering News Record, June 26, 1919. p. 1254.

Mimeographed Articles

Specifications for water-gas tar (American Wood Preservers Association, 1917).

Wood Creosotes

Journal Articles

°On the toxicity to a wood-destroying fungus of maplewood creosote and of some of its constituents and derivatives, together with a comparison with beechwood creosote - Pieper, Acree, Humphrey; Journal of Industrial and Engineering Chemistry, June, 1917.

°The chemical composition of the higher fractions of maplewood creosote - Pieper, Acree, Humphrey - Journal of Industrial and Engineering Chemistry, May, 1917.

Preservatives (Cont.)

Zinc Chloride

Bulletins and Circulars

^{oo}Forest Service Circular 190 - A visual method for determining the penetration of inorganic salts in treated wood -- 1911.

Journal Articles

^{o}The relation between the specific gravity of zinc chloride solutions and their concentrations - Bateman; Wood Preserving, July - Sept., 1916.

^{o}Method of determining the amount of zinc chloride in treated wood - Bateman; Journal of Industrial and Engineering Chemistry, Jan., 1914.

^{o}A comparison of zinc chloride with coal-tar creosote for preserving crossties - Weiss; Proceedings of American Wood Preservers Association, 1913,pp.81-83.

^{o}The apparent relation between rainfall and durability of zinc treated ties - Teesdale and Allen; American Wood Preservers Association, 1919.

^{o}Results of some tests of the effect of zinc chloride on the strength of wood - Wilson and Bateman; American Wood Preservers Association, 1921.

Mimeographed Articles

Preservation of timber by the steeping process.
Specifications for zinc chloride - American Wood Preservers Association, 1918.
List of principal consumers of zinc chloride for wood preservation in the United States.
List of manufacturers of zinc chloride.

Sap Stain and Molds

Bulletins and Circulars

°°Forest Service Circular 192 - Prevention of sap stain in lumber - 1912; 5 cents.

Mimeographed Articles

Forest Service experiments in the prevention of sap stain in lumber.
Suggested experiments with sap stain preventives.
Sap stain and molds on lumber.

Technical Notes

133 Difference between molds and wood destroyers.
136 Killing molds on lumber by steaming.

Service Tests

Bulletins and Circulars

Forest Service Circular 198 - Condition of experimental chestnut poles in the Warren-Buffalo and Poughkeepsie-Newton square lines after five and eight years' service - 1912 - 5 cents.

°°Forest Service Circular 209 - Service Tests of Ties - 1912.

°Forest Service Bulletin 51 - Report on condition of treated timbers laid in Texas, Feb., 1902-1904; 10 ¢.

Journal Articles

°Laboratory tests on the durability of American woods - Humphrey; Mycologia, Vol. 8, March, 1916, pp. 80-92.

°Tests on the durability of greenheart - Humphrey - Mycologia, Vol. 7, July, 1915, pp. 204-209.

°Service tests of treated and untreated telephone poles -- Teesdale; Telephony, April 3, 1915.

Service Tests (Cont.)

Journal Articles

°Records on the life of treated timber in the United States - Weiss and Teesdale - American Wood Preservers Association, 1915. pp. 501-509.

Service tests of treated and untreated fence posts - Bradley - American Railway Engineering Association Bulletin 187, July, 1916.

°Service tests of posts and poles - Hicks; American Wood Preservers Association, 1917.

°Service tests of ties in the C. and N. W. Ry., near Janesville, Wis.; N. P. Ry., near Plains, Mont.; and N. P. Ry. near Maywood, Wash. -- Teesdale; American Railway Engineering Association Proceedings, March, 1916, p. 463.

°Tie durability records - Winslow and Teesdale - American Railway Engineering Association Proceedings, March,1916, p. 463.

°Service tests of crossties - Teesdale and Winslow - American Wood Preservers Association Proceedings, 1916, pp. 265-330.

°Service tests of crossties - Hicks; American Wood Preservers Association Proceedings, 1917, pp. 85-228, and American Railway Engineering Association Proceedings, 1917, pp. 1291-1435.

°Service tests of crossties - Hicks - American Railway Engineering Association Proceedings, 1918.

Catalogue of service test records of ties - American Wood Preservers Association Proceedings, 1920, pp. 93-131.

Service tests of treated and untreated poles - Hicks; National Electric Light Association.

°Experiments with butt-treated poles in California - Hicks -- American Wood Preservers Association Proceedings, 1921.

Service Tests (Cont.)

Journal Articles (Cont.)

Service tests of treated and untreated fence posts - MacLean; American Wood Preservers Association Proceedings, 1921.

Mimeographed Articles

Durability of treated and untreated piling above mean low water.

Shingles

Journal Articles

°Fireproofing wooden shingles - Weiss; American Roofer, December, 1915.

Mimeographed Articles

Fireproofing of wood.
Preservative treatment and staining of shingles.

Silos

Journal Articles

The preservative treatment of wooden silos - Hunt; American Lumberman, March 13, 1915.

Mimeographed Articles

List of manufacturers of silos.

Storage Problems

Bulletins and Circulars

°Department of Agriculture Bulletin 510 - Timber storage conditions in the eastern and soithern states with reference to decay problems - 1917; 20 cents.

Journal Articles

°Rot in stored lumber - Humphrey; American Lumberman, August 14, 1915, pp. 32 - 33.

Piling lumber to prevent deterioration - Helphenstine; Hardwood Record, July 25, 1920.

Technical Notes

A-1 Hints on storing lumber to prevent decay.
A-4 Preventing damage to logs in storage.

Wood Blocks

Bulletins and Circulars

°°Forest Service Circular 141 - Wood paving in the United States - 1908.

°°Forest Service Circular 194 - Progress report on wood paving experiments in Minneapolis - 1912.

Journal Articles

°Condition of creosoted wood block pavements in Mobile, Ala., Shreveport, La., and a number of Texas cities - Teesdale; American Wood Preservers Association Proceedings, 1918.

°Progress report on wood block paving experiments in Minneapolis - Teesdale and MacLean - American Wood Preservers Association Proceedings, 1919, and Engineering News Record, Jan. 30, 1919.

Wood Blocks (Cont.)

Journal Articles (Cont.)

°The treatment of wood paving blocks - Teesdale; American Society of Municipal Improvements, 1916; Canadian Engineer, Oct. 26, 1916; Good Roads, Dec.2,1916.

°Treated wood block for factory flooring and miscellaneous uses - Teesdale; American Wood Preservers Association Proceedings, 1916, pp. 202-210.

°Bleeding and swelling of paving blocks - Teesdale; American Wood Preservers Association, 1915, pp. 372 - 397.

°History of treated wood block pavements in the United States - Teesdale; American Wood Preservers Association, 1915, pp. 324 - 367.

°Experiments on the bleeding and swelling of southern yellow pine paving blocks - Teesdale; American Society of Mun. Imp., 1914, pp. 267 - 286.

°Experiments with wood paving blocks (Minneapolis) - Teesdale; Municipal Journal, May 6, 1915.

Mimeographed Articles

Specifications for preservatives for paving blocks (American Wood Preservers Association, 1917)

Specifications for wood block paving - (American Wood Preservers Association, 1917)

List of some of the more important literature on wood block pavements.

List of companies in the United States manufacturing creosoted wood blocks.

Wood Pipe

Bulletins and Circulars

^{o}United States Department of Agriculture Bulletin 155 - Wood pipe for conveying water for irrigation - 1914; 10 cents.

^{o}United States Department of Agriculture Bulletin 376 - Flow of water in wood stove pipe - 25 cents.

Wood Preservation in General

Bulletins and Circulars

^{oo}Forest Service Circular 139 - A primer of wood preservation - 1908.

^{o}Forest Service Bulletin 78 - Wood preservation in the United States - 1909; 10 cents.

^{o}Forest Service Circular 134 - The estimation of moisture in creosoted wood - 1908; 5 cents.

^{oo}Forest Service Bulletin 41 - Seasoning of timbers - 1903.

^{oo}Forest Service Circular 101 - The open-tank method for the treatment of timber - 1907.

Journal Articles

A theory on the mechanism of the protection of wood by preservatives - Bateman; American Wood Preservers Association, 1920, pp. 251 - 255.

Brush coat should follow trimming of treated timber - Hunt; Engineering News Record, April 15, 1920.

Inaccuracy of treating records due to moisture in wood - Bateman; Chemical and Metallurgical Engineering, Jan. 14, 1920.

Wood Preservation in General (Cont.)

Journal Articles (Cont.)

Decay in wooden bleachers - Teesdale; Engineering Record, Oct. 3, 1914, and American Lumberman, Oct. 3, 1914.

°Temperature changes in wood under treatment - Hunt; American Wood Preservers Association Proceedings, 1915, pp. 85 - 100.

°Preservative treatment of Timber - Weiss and Teesdale; International Engineering Congress - 1915.

°The preservation of wood from decay - Teesdale; Armour Engineer, March, 1915.

°How the wood preserving industry can avoid possible injury resulting from the war - Teesdale; Engineering Record, Sept. 29, 1914; Manufacturers Record, Sept. 24, 1914; Southern Lumberman, Sept. 26, 1914; Railway Age Gazette, Oct. 21, 1914.

°Records on the life of treated timber in the United States -- Weiss and Teesdale; American Wood Preservers Association Proceedings, 1915, pp. 501 - 509.

°Timber preservation - Winslow; Electric Traction Weekly - 1911.

°Preservation of structural timbers from decay - Winslow; Proceedings Engineering Society of Western Pennsylvania; Dec., 1910, Vol. 26, No. 9, pp. 247 - 451.

°Structure of commercial woods in relation to the injection of preservatives - Weiss; American Wood Preservers Association Proceedings, 1912, pp. 159 - 187.

°Air seasoning of timber - Kempfer - American Railway Engineering Association Bulletin 161.

°Sanitary handling of timber - Humphrey; Southern Lumberman; April 1, 1916.

Wood Preservation in General (Cont.)

Journal Articles (Cont.)

°Protecting wood from decay and fire - Teesdale; Scientific American, October 20, 1917.

°The transmission of air pressure in crossties - Winslow; American. Wood Preservers Association, 1913, pp. 81 - 83.

Mimeographed Articles

Partial bibliography of the American wood preserving industry.
List of creosote producers and dealers in the United States.
List of companies which handle sodium fluoride.
List of manufacturers of zinc chloride.
List of references to literature on the decay of wood.
List of companies equipped to build treating plants.
Treatment of factory roof timbers.

Technical Notes

A-1 Hints on storing lumber to prevent decay.
A-3 How to make factory roof timbers last longer.
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U. S. Department of Agriculture, Forest Service

FOREST PRODUCTS LABORATORY

In cooperation with the University of Wisconsin

MADISON, WISCONSIN

PRESERVATIVE TREATMENT OF WOODEN SILOS

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PRESERVATIVE TREATMENT OF WOODEN SILOS

The amount of lumber which is used each year in the construction of wood stave silos is not always appreciated. While no exact figures are obtainable, one estimate places the amount used in 1913 at about 100,000,000 feet, b. m. and this, of course, was high grade lumber.

While many other materials such as brick, tile, and concrete are being advocated and used to a large extent the popularity of wood continues. Each class of material has certain advantages and disadvantages, but no one material possesses all of either. The fact is that a good silo can be made of any of a number of materials if the proper care is used in its construction and maintenance. The usefulness of any kind of silo is largely dependent upon the care it receives, and this is especially true of the wooden silo. It has been stated on good authority that a large percentage of the failures in wooden silos is due to some form of neglect.

Some of the advantages of wood stave silos are cheapness, lightness, ease and quickness with which they can be erected, smoothness of the sides, and the fact that they can be purchased all complete and ready to set up. Three important disadvantages of wood are the shrinkage of staves in summer, the necessity for frequent painting and, with some kinds of timber, their lack of durability.

Desirability of Treatment

The desirability of preservative treatment is becoming generally recognized. Several manufacturers of wooden silos are already treating all of their silo material and it is now possible to purchase silos treated and ready to set up. The use of treated silos is comparatively recent, however, and it is too soon in most cases for the results of the treatment to be entirely apparent. So much study has been put into the treatment of other forms of timber, however, and the results are so well known, that the effect of silo treatment can readily be predicted. That the life of the staves will be greatly increased by proper treatment is beyond doubt. It is not unreasonable to expect that with a good pressure treatment with coal-tar creosote a silo will resist decay for at least twenty-five or thirty years. Laboratory experiments have shown that creosoted wood does not absorb as much water as untreated wood, and the rate of absorbtion is much slower. Since shrinking and swelling are dependent on the absorption of water, this indicates that their effect will be less in a treated silo than in an untreated one, and less attention will be required to keep the hoops tight. This has been reported to be the case in several instances. The presence of the oil in the wood also tends to prevent warping and checking, and the necessity for painting is obviated.

In the dimensions used in silo construction it is possible to treat satisfactorily most species of wood which are otherwise suitable for the work. Some species are more resistant to treatment than others, however, and the most efficient treatment can be obtained with the less resistant woods. Of the woods in general use for silo construction the pines are as a class the most easily treated, while hemlock, tamarack, spruce and Douglas fir treat with greater difficulty. In general, the sapwood of any species is much more easily treated than the heartwood. The exceptions to this rule are hemlock and redwood, the sapwood of these being as difficult to penetrate as the heartwood. With pressure treatment the greatest saving can usually be effected by using the cheapest wood, as the difference in durability between the various species is less after treatment than before. Staves of part or all sapwood can be made durable, hence there is no necessity for specifying all heartwood if a good treatment is to be given. It is questionable if the treatment of such durable species as heart cypress and redwood would pay.

Preservatives

Of the various wood preservatives now in general use a good grade of coal-tar creosote is very satisfactory for preserving timber from decay. There are also several oils sold under proprietary names which are derived from creosote.

A number of them have given good results in durability tests. The quality of creosote is of particular importance for silo work, and care should be taken that a high grade of oil is used. For the brush, open tank and dipping treatments an oil of comparatively high specific gravity (around 1.08) at 60° C. is preferable. For pressure treatments a lower specific gravity (1.03 to 1.08) should be just as satisfactory, and more economical. In no case should an oil containing a high percentage of low boiling oils be used. A list of the principal creosote producers and dealers in the United States has been compiled by the Forest Service and can be obtained by writing to the Forest Products Laboratory, Madison, Wis.

Undistilled tar used by itself does not give as good penetrations as the distillate creosote and it has low fungical properties. The latter oil is, therefore, to be preferred.

Water soluble salts such as zinc chloride appear to be unsuitable. Experiments have indicated that zinc chloride is readily leached out of the wood by the moisture in the silage. The contamination of the silage by the zinc chloride would tend to retard the silage forming processes and might also have a deleterious effect on the cattle. Furthermore, zinc chloride and other water soluble salts would not retard shrinkage and swelling or obviate the necessity for painting.

Methods of Applying Preservatives

Four methods in ordinary use for applying creosote are impregnation under pressure, open tank treatment, dipping, and brush treatment, The choice of a method will depend on the apparatus available, the amount of wood to be treated, the expense permissable and the durability desired.

The best results will be obtained by impregnation under pressure on account of the better absorption and penetration of oil which can be secured. In this method of treatment the wood is placed in a steel cylinder and the oil forced into it at a high pressure. An absorption of about eight to ten pounds of oil per cubic foot of wood need not be exceeded, and the oil should be distributed as evenly as possible throughout the wood. The treatment should be made in a way which will reduce the subsequent bleeding of preservative to a minimum. The apparatus required for pressure treatment is expensive, and the method is practicable only when large amounts of timber are to be treated. In some cases it might be possible for a farmer to haul his silo timber to a commercial treating plant and have it treated, but in general the use of the pressure process will be limited to manufacturers of silos. As a rule it would probably be cheaper for them to have their material treated under contract with some commercial treating plant, but in some cases the output of the silo factory might be sufficient to justify the erection of a small pressure plant.

If pressure treatment can not be given good results can be obtained by an open tank treatment. In this treatment the wood is first heated in creosote for one or two hours at a temperature of 180° to 220° F., then quickly transferred to a tank of cold oil where it is held for one or more hours, until the desired amount of oil is absorbed. The function of the hot bath is primarily to heat the wood and expand the air and moisture it may contain. The sudden cooling of the wood when immersed in the cold bath causes the air and moisture to contract and produce a partial vacuum, which draws the oil into the wood. Comparatively little absorption takes place in the hot bath, except with certain very easily treated woods. The cold bath is sometimes dispensed with and the absorption of oil obtained by discontinuing the heating of the hot bath, and allowing the hot wood and oil to cool together. This accomplishes the same result as the cold bath, but requires a considerably longer time. By the open tank process good absorptions and penetrations can be obtained in any wood which is not resistant to treatment.

Apparatus Required and Variants of Treatments

The apparatus required for these treatments consists of one or two tanks (depending on whether the cold bath or cooling bath is used), with suitable means for heating, and a thermometer. The dimensions of the tanks should be such that

the wood can be completely immersed in the oil, and they must be deep enough to keep the oil from slopping over the sides of the tank and taking fire, as this may cause the loss of both the wood and the oil. Care should be taken also that the oil does not get too hot, as this may cause it to boil over. A temperature of 220° F. should not be exceeded. The heating may be accomplished either by means of an open fire, or by steam coils.

In the dipping treatment the wood is usually immersed in hot oil for from five to fifteen minutes. A longer time would be still better. This allows the cracks and checks to become filled with the preservative, but except in cases of woods which are very easily treated the absorption and penetration of preservative are slight. The same kind of a tank is required as in the open tank process. On a commercial scale the dipping is usually accomplished by passing the staves on a conveyor through a tank of hot oil. The length of time the staves remain immersed in the oil is determined by the speed of the conveyor. Since the amount of time required and oil consumed are much less than in the open tank treatment dipping is much the cheaper. The effectiveness of the treatment is also considerably less.

The simplest and cheapest treatment of all is the brush treatment. It is also the least effective. The oil is

heated to about 180° to 220° F. and applied with a brush. Two coats are ordinarily used and the oil is flooded over the wood rather than painted on it. The second coat is not applied until the first coat has completely dried. Particular care should be exercised to see that every part of the wood is treated, and every check and flaw should be completely filled with the preservative. The apparatus required consists simply of a brush or an old broom, and a bucket or kettle in which to heat the oil. When a thermometer is available it is of considerable assistance in regulating the temperature of the oil. Aside from the simplicity of apparatus and the ease of treatment, another advantage of this process is the fact that no excess of oil need be left on hand after the treatment is finished.

A modification of the painting process which is sometimes used by manufacturers consists in passing the staves through a machine in which creosote is sprayed upon them from all sides.

While the increased life resulting from brush treatment will probably be less than that from the other treatments, it can be expected to more than justify the cost.

Since the bottom of the stave is where decay usually causes the most trouble, a very good combination treatment would be to give the lower two or three feet of each stave a hot and cooling bath treatment, and the rest of it a 2-coat

brush treatment. In this way the most vulnerable part of the silo would receive the heaviest treatment. By making the tank treatment first and the brush treatment afterward little or no excess oil need be left on hand after the treatment is finished.

After the staves have been treated by any process they should be openly piled and allowed to thoroughly season before erecting the silo. Some time should also elapse if possible after the silo is erected before it is filled. This will lessen the chances of contamination of the silage by the creosote.

If possible, every stick should be cut to the proper dimensions before treatment. The effectiveness of these treatments is dependent upon maintaining an unbroken zone of treated wood over the entire surface of every piece. Cutting the wood after treatment exposes untreated surfaces, and offers an opportunity for decay to enter. If it is necessary that a treated stick be cut the exposed end should be thoroughly painted with creosote before being put into its place.

Cost of Treatment

A close estimate of the cost of treatment by the various processes is very difficult to make, owing to the number of variable factors which must be taken into consideration. The cost of treatment on a large scale by the manufacturer

can best be learned by applying to the manufacturers themselves. If the farmer wishes to creosote his own silo, however, the following estimates may be of some assistance. These estimates are not to be taken as conclusive but rather as approximations of the cost under the conditions given.

In the open tank treatment the amount of oil absorbed will vary with the species of wood used and the thoroughness of the treatment. Assuming that five pounds of oil per cubic foot will be the average absorption, and that the cost will be 20 cents per gallon, and estimating labor at $2 per day, the cost of oil and labor would be about as follows for a silo containing 3,000 board feet.*

150 gallons of creosote at 20¢.....	$30
3 days' labor at $2..............	6
Total.................	$36

Very easily treated woods like sap pine would probably absorb more oil, while woods which are more difficult to treat, like heart tamarack, spruce, and Douglas fir, would absorb less. In addition to that absorbed, several inches of oil would be left in the bottom of the tank. If provision can be made to use this in other ways about the farm its cost need not be charged against the silo treatment. The cost of the treating tanks is not included in the above estimate.

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*A 14 x 34-foot silo made of 2-inch lumber contains about 2,990 board feet exclusive of the roof. (The cost of creosote has risen considerably since this estimate was made.)

Brush treatment can be given much more cheaply. For a silo of the size mentioned above about thirty gallons of creosote would be required for a 2-coat brush treatment. At 20 cents per gallon this would cost $6 and the labor at $2 per day would probably amount to about $6, or a total of $12.

A dipping treatment would absorb more oil than brush treatment, making the cost a few dollars more.

The cost of giving the butts of the staves an open tank treatment and the remainder a brush treatment would be about as follows for a silo of the dimensions given above:

42 gallons of creosote at 20¢ per gallon....	$8.40
3 days' labor at $2 per day................	6.00
Total...........................	$14.40

Contamination of Silage

In 1910 a coöperative experiment was inaugurated by the University of Wisconsin and the Forest Products Laboratory to obtain information on the durability of treated wood in silage, and upon the contaminating effect of the preservatives. Billets of wood treated in various ways were placed in one of the university silos during the process of filling, and covered with the silage. None of the sticks have, as yet, started to decay, but some information on contamination was obtained during the first season. When they were

uncovered during the course of feeding out the silage, analysis of the material near the billets treated with zinc chloride showed that considerable zinc chloride had leached out into the silage. This took place even though the billets were painted with a coat of red lead.

The amount of creosote present was not sufficient to determine by analysis, but there was enough to give a strong odor to the silage immediately surrounding the creosoted sticks. This creosote contaminated silage was collected by itself and fed to the cattle. It was not relished by them, and two of the cows were slightly "off their feed" for a day or two. This, of course, was a very severe test, and if the contaminated silage had been mixed with the rest of the silage the effect would have been less pronounced. Since several of the treated sticks were given a much heavier absorption than is now considered advisable, and they were all placed in the silage within a few days after treatment, it is felt that the conditions in this experiment were much more severe than would obtain in a creosoted silo, and the results do not indicate that serious contamination would take place in the latter.

Considerable weight is given to this opinion by the results of a recent investigation. Letters were sent to all the agricultural experiment stations in the country, and to all users of creosoted silos who could be located. While but few

of the experiment stations had had any experience with creosoted silos, and only a small number of owners of such silos could be located, not a single case was reported where the silage had been damaged or the health of appetite of the stock affected. It was the general opinion of the experiment stations that no danger need be anticipated on this account.

In order to obtain further information on this point an experiment is now being carried on by the University of Wisconsin in coöperation with the Forest Products Laboratory. While this experiment will not be concluded for a number of years it is expected that the coming feeding season will yield some valuable data.

Summary

1. The amount of lumber used in silo construction is so great that it is of considerable economic importance to increase its length of life by preservative treatment.

2. Coal-tar-creosote is an excellent preservative for the prevention of decay in timber.

3. The advantages of a thorough creosote treatment appear to be:

(a) A material increase in durability.
(b) A decrease in the amount of attention required to keep the hoops tight.
(c) The necessity of painting is obviated.
(d) Greater stability to the silo.

4. The thoroughness and cost of treatment are about in the following order for the various methods beginning with the most thorough and most expensive:

Impregnation under pressure, open tank treatment, dipping, brush treatment.

5. No appreciable contamination of silage by contact with creosoted staves has been observed in the instances reported. Proper care in the treatment and thorough air seasoning after treatment should reduce the danger of contamination to a minimum.

U. S. Department of Agriculture, Forest Service
FOREST PRODUCTS LABORATORY
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MADISON, WISCONSIN

USE OF FLUORIDES IN WOOD PRESERVATION

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USE OF FLUORIDES IN WOOD PRESERVATION

Sodium fluoride seems destined to play an important part in the future of wood preservation. It has properties which make it appear to be well adapted for the treatment of wood against decay, and tests are now under way to determine its efficiency in actual service.

The antiseptic properties of several of the fluorine compounds have been known for many years. Through the work of Professor Effront at Brussels the use of hydrofluoric acid became general in breweries for the prevention of wild yeast growths in mash. The prominence thus given to this acid led to a study of its use as a wood preservative, which was taken up about 1900 in Austria under the direction of Basilius Malenkovich.

The first work was done on hydrofluoric acid, and a patent was taken out covering the use of free hydrofluoric or free hydrofluorsilicic acid, with or without the addition of other fluorides. The process was later modified by adding zinc chloride to an excess of the acid solution, forming zinc acid fluoride (ZnF. HF). In Germany the Wohlman process, a combination salt, including sodium fluoride, was introduced and is still being used.

About 1906, Basilius Malenkovich further improved his process by impregnating wood with a solution containing about

equal amounts of sodium fluoride and zinc chloride. He claims that either on heating above 60°C., or by allowing the wood to season out, the zinc chloride and sodium fluoride react with each other, forming zinc fluoride (ZnF_2) and sodium acid fluoride (2NaF. HF.)

Subsequent to 1903 various patented and secret compounds which contained sodium fluoride or other fluorides as the main toxic agent made their appearance in Germany and Austria. Many of these consisted of a solution of sodium fluoride and highly toxic organic compounds, as, for example, dinitriphenol. These preservatives were especially recommended for use in buildings for the prevention of dry rot in wood, growths of mold, etc.

The use of the fluorine compounds attained its greatest development in Austria, where in the years subsequent to 1907, several thousand telegraph poles were treated by the Austrian State Telegraph Bureau.

The fluorides possess higher antiseptic properties than most of the other metallic salts commonly used in wood preservation, with the exception of mercuric chloride. Table 1, which is taken from Bulletin 227 of the United States Department of Agriculture, contains the results of many investigators on this subject.

Sodium fluoride is from 3-1/2 to 4-1/2 per cent soluble in water, whereas zinc chloride is soluble in water in all

proportions. In Bulletin 145 of the Department of Agriculture, entitled, "Tests of Wood Preservatives," experiments on the use of sodium fluoride in wood preservation are given which show that the salt penetrates the wood satisfactorily, that it has but little influence on the inflammability of wood, and that it is practically noncorrosive in contact with iron or steel; also that wood treated with it can be painted without any apparent effect on the paint. Strength tests made on wood treated with this salt indicated that there was no apparent effect upon the mechanical properties of the wood.

Since it was very desirable to find a preservative which after injection into wood could be satisfactorily painted, further tests were made on this phase of the question.

Several panels were treated with sodium fluoride and zinc chloride, and after being painted with white lead and zinc oxide paint were exposed to the weather in different sections of the country. After 18 months of exposure the panels treated with zinc chloride were in much less satisfactory condition than those treated with the sodium fluoride. In the former case the paint peeled off and exposed the unprotected wood, whereas there was no visible difference between* the panels impregnated with sodium fluoride and those which were not impregnated.

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*See Bulletin 51 of Paint Manufacturers' Association, entitled: "Report on Impregnated Panel Tests and Fire Retardent Paints," by Henry A. Gardner.

Satisfactory durability records on the use of sodium fluoride are lacking. Quite a number of the poles which were treated by the Austrian investigators were set aside for test purposes and have been reported on from time to time. No reports have been obtained on these poles since 1913, however. The latest results available are given in Tables 2, 3, and 4*. Other poles treated with copper sulphate and with coal-tar creosote are included for comparison.

In view of the apparent success which attended the use of the fluoride salts in Europe, the Forest Products Laboratory in 1912 undertook experiments for comparative results with sodium fluoride, zinc chloride, and the zinc chloride and sodium fluoride mixture developed by Malenkovich. After preliminary experiments about 450 shortleaf pine mine ties were treated and installed in the Birmingham district in the spring and summer of 1914. These ties were divided into lots of 50, treated with three concentrations of each preservative. Fifty ties were given a treatment of 0.25 lb. per cubic foot of dry salt, an equal number with 0.5 lb., and an equal number with 0.75 lb. per cubic foot. After air-seasoning these ties were placed in the mine with 100 similar untreated ties and 50 creosoted ties.

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*Robert Nowotny: Erfahrungen aus der Praxis der Holzimpraegnierung mit Fluoriden. Zietschrift für angewandte Chemie, Jahrgang 26, Nr. 93. Vm. 21, November, 1913.

In the fall of 1914 another service test was started on the Baltimore & Ohio Railroad, near Baltimore, Md., in which 300 red oak ties treated with 0.5 lb. of sodium fluoride per cubic foot were installed in a test track, together with ties treated with zinc chloride, creosote, and various other preservatives. In both of these tests the ties have been in service for too short a time to give results. It is expected, however, that these experiments will ultimately give valuable data on the suitability of sodium fluoride as a wood preservative.

The present European practice in impregnation treatments of sodium fluoride is to inject from 0.4 to 0.5 lb. of sodium fluoride per cubic foot of wood. Where the sodium fluoride and zinc chloride process is used, about 1/4 lb. of each is injected per cubic foot.

Sodium fluoride appears to be especially suited as a preservative for wood to be used in warehouses, dwellings and various other kinds of building construction. For this purpose it can be applied to the timber by the so-called steeping process, in which the wood is allowed to soak in vats containing a solution, or it can be applied to better advantage at a central treating plant by means of the pressure process. It is believed to be better fitted for this character of work than any of the other common wood-preservatives; for example, it has the advantage of zinc chloride

of being less deliquescent, and hence does not absorb moisture from the air so readily, and it also appears to have no effect upon paint coatings.

Unlike mercuric chloride, sodium fluoride is not a very poisonous material, and it is not corrosive on iron or steel. Hence, it can be applied in steel tanks. It is also very much cheaper than mercuric chloride.

In view of its highly toxic properties, it seems likely that sodium fluoride will ultimately find favor in the treatment of ties, mine timbers, etc. If the use for this material is largely increased, it seems very likely that the price can be reduced to compare very favorably with that of zinc chloride.

Experiments with the use of sodium fluoride in preventing sap stain were also conducted by the Forest Products Laboratory, the first experiments being made about 1912. More recently tests in co-operation with a lumber mill operating on Southern yellow pine and with one on the Pacific Coast operating on Western yellow pine and Western white pine were completed. More extensive tests are planned for 1916 on Southern yellow pine and on Northern hardwoods.

As a result of the tests thus far made, the sodium fluoride appears to be effective in preventing the growth of the sap-stain fungus. It also has the advantage of being

toxic, and thus destroys the spores of any fungi which happen to alight on the surface of lumber dipped in the solution. Lumber dipped in sodium fluoride is, therefore, in an antiseptic condition, and is consequently much less liable to decay before it reaches the consumer than lumber which has not been dipped. The exact strength of solution which it is necessary to use has not been determined.

Comparatively speaking, the production of sodium fluoride has been small. In 1912 the production in Europe was about 220,000 lbs., most of which was used in wood preservation. In this country the production is very much smaller, but is tending to increase.

Sodium fluoride is being used for a variety of purposes, one of the most important of which is as an insect exterminator. If the production could be greatly increased, it seems likely that the cost of the product could be reduced very much. This was found to be true in Europe, where the cost at first was about 8 cents per pound. When it was developed as a wood-preservative, however, and the production increased, the price was reduced to 3.7 cents per pound for 80 per cent pure sodium fluoride. This compares with their cost of about 3.2 cents per pound for 100 per cent zinc chloride.

In this country sodium fluoride is made by treating fluorspar (CaF_2) with sulphuric acid, thus producing hydrofluoric acid. This is passed into sodium carbonate or caustic

soda solution, forming sodium fluoride. Cheaper processes than these have been developed in Europe, where much sodium silico fluoride (Na_2SiF_6) is produced as a by-product in the manufacture of acid phosphate from phosphate rock. The sodium silico fluoride is fused with sodium hydroxide, forming sodium fluoride and silicon hydroxide. This sodium fluoride as marketed contains about 20 per cent of silicon dioxide, and is, therefore, 80 per cent pure.

There appears to be no reason why sodium fluoride cannot be produced in this country as a by-product of superphosphate, as our phosphate rock contains considerable fluorine, and manufacturers are said to be willing to make the fluorides, provided there is a demand for them.

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THE PRESERVATIVE TREATMENT AND STAINING OF SHINGLES

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The preservative treatment of dry shingles is easily accomplished by immersing them for about one hour in a tank of creosote (dead oil of coal tar) heated to a temperature of about 212° F. In the case of damp or green shingles, it is often necessary to prolong this period in the hot oil. If, at the end of the hot bath, it is found that the oil has not thoroughly penetrated the wood, the heat may be shut off and the shingles allowed to remain in the cooling oil for an hour or more; or else they may be removed from the hot oil and quickly plunged into a cooler bath of the preservative, preferably at about 110° F.

Staining of the shingles can also be accomplished in the same process. Any of the common colors can be used. They should be purchased ground in oil, not dry. Of the reds or browns, about one-half pound is required for each gallon of creosote. For greens or blues, this quantity should be increased. The color should be mixed with an equal quantity of boiled linseed oil and then stirred thoroughly into the creosote, at a temperature of about 110° F.

The shingles should be immersed in the bath of hot creosote (212° F.) If they are thoroughly seasoned, one-half hour in the hot oil will be sufficient. They should then be plunged in the cooler creosote and color and allowed to remain

for about two hours. In this bath the shingles must be loose in order to permit an even deposit of the stain. A screen or lattice-work frame will assist in keeping the shingles under the oil. As a final step, the shingles should be spread out to dry.

If no suitable iron vats are available, the treating tanks may be constructed by a boiler maker, or sheet-iron worker. The hot tank need be only large enough for the immersion of a single bundle of shingles, unless it is desired to use it for the treatment of fence-posts or other timbers. If the heat must be applied by direct fire underneath, the metal should be heavy enough to withstand the flame,-say 3/16-inch black iron, with the joints riveted and caulked. If steam coils can be used, the tank may be of fairly light galvanized iron, the joints being riveted and soldered. The tank for the cool oil can be made of light galvanized iron.

The cost of the treatment depends principally upon the local price of creosote and the quantity of shingles which it is desired to treat. If the process is properly carried out, however, the cost of a creosoted low-grade shingle should not exceed the first cost of a high-grade shingle of the same kind, nor should the cost of creosote and staining exceed that of thorough painting; and it is believed that the results are more desirable in every way.

THE FIREPROOFING OF WOOD

A great many experiments have been made at the Forest Products Laboratory on methods of fireproofing wood and shingles. The results of a large number of these experiments are included in an article by R. E. Prince, entitled "Tests on the Inflammability of Untreated Wood and of Wood Treated with Fire Retarding Compounds," which was published in the 1915 proceedings of the National Fire Protection Association, pages 108 to 158. Reprints of the article can be obtained for 25 cents from the Secretary of the association at 87 Milk Street, Boston, Massachusetts.

Wood may be made fire retardent by injecting, under pressure, solutions of certain chemicals such as ammonium sulphate, ammonium phosphate, ammonium chloride, sodium borate, etc. If a sufficient quantity is injected, the wood after drying becomes so fire resistent that it will not support combustion. If held in a hot flame it will char and in time fall to pieces, but it does not burn with a flame and will stop burning almost immediately after being removed from the flame. There are two objections to this method of fireproofing wood. One is that the cost of the chemicals and the expensive nature of the apparatus used for injecting them make the treatment expensive. This

eliminates the method from consideration as a means by which one can economically fireproof a small amount of material for his own use. There is one company in the country, however, which is treating timber with chemicals in this way for the market.

A second objection to the use of the chemicals mentioned above is the fact that they are all soluble in water, and if the wood is used where it will be exposed to the action of water the chemicals will be washed out in time and the wood will lose its fire-resisting qualities. A method of treatment has been developed at the laboratory, however, by which this objection is overcome.

This method consists essentially in treating the air-dried wood or shingles with a solution of borax in water. The wood is then kiln dried to about 10 per cent moisture and given a second treatment with a zinc chloride solution. The wood is again dried and is then ready for use. The solutions must be applied under heavy pressure, and retorts capable of withstanding high pressure are necessary, together with pressure pumps, measuring tanks, and other comparatively expensive equipment. Theoretically, the process depends upon the formation of an insoluble salt by the zinc chloride and the borax. This salt is practically insoluble in water and the treated wood can, therefore, be used in exposed situations. Under the action of heat the

salt fuses, coating the cell walls and rendering them resistent to fire. Test shingles treated by this method and soaked in running water for two weeks still retained their fire-resistent properties. The process has been developed in an experimental way only, and thus far no shingles treated by this method are being placed on the market.

There is a method, however, by which the inflammability of wood can be reduced and which is practicable on a small scale. This is by the use of fire-retardent paints. There are a considerable number of paints on the market sold under various names as fire retardents. Some are suitable for inside use only and a few are suitable for use on wood exposed to the weather. Some, of course, are better than others. The results of the tests made at the Forest Products Laboratory on a number of these paints are given in the article mentioned above. Other tests are reported in the proceedings of the National Lumber Manufacturers' Association, 1916, pages 96 to 117.

The more effective of the fire-retardent paints afford considerable protection to the wood and greatly decrease its liability to catch fire from a spark or a small flame. One paint especially suitable for outside use has been developed at the laboratory, of which zinc

borate and linseed oil are the principal ingredients. This was about the most resistent of the paints tested at the laboratory, and maintained its fire-resisting properties through three years of exposure to the weather. Another material which gives good results is ordinary calcimine, but, of course, it is not very suitable for outside use.

The cost of using fire-retarding paints should be approximately the same as using ordinary high grade paints.

G. M. H.

March 21, 1917.

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
FOREST PRODUCTS LABORATORY
MADISON, WISCONSIN
(In Cooperation with the University of Wisconsin)

THE TREATMENT OF FACTORY ROOF TIMBERS

By
Geo. M. Hunt
Chemist in Forest Products

March 18, 1919

THE TREATMENT OF FACTORY ROOF TIMBERS

The exact method of treating timber in order to get the best service in paper and cotton mill roofs and roofs in other buildings where high humidity conditions cause rapid decay has never been worked out. A number of excellent preservatives are known and their use has been recommended from time to time. There are practically no records of the service given by treated roofs, so all recommendations have to be based on information available from other uses of treated timber. Specific recommendations are difficult due to the wide variation in local conditions, such as the amount of timber to be treated, the expense permissible, insurance regulations, and the availability of treated timber. Several possible methods of treatment are given and the circumstances surrounding each individual case should suggest which one to use.

Untreated Timber

Untreated roofs of non-durable wood, such as spruce, hemlock, or sappy pine, are cheapest in first cost, but if the humidity in the building is high they decay rapidly and soon need to be replaced. The need for frequent replacement may make them more expensive than roofs whose first cost is considerably higher.

Some woods are naturally much more durable than those mentioned, and they can sometimes be used to advantage where circumstances preclude the use of treated timber. The most durable American woods which can be readily secured in quantity for roofing purposes are redwood, bald cypress, Port Orford cedar and western red cedar. In using these species care should be taken to select heartwood only, as their sapwood is not very durable.

Treated Timber

Methods of treating timber with preservatives vary in cost and effectiveness. Some require only very simple apparatus and the treatments can be made at the building site. Others require heavy pressure and special apparatus, and must, therefore, be made at central treating plants. The following is a brief description of two generally used treatments.

The Steeping Process

This method of treatment consists in simply soaking the timber in a water solution of the preservative. It is suitable for preservatives such as zinc chloride, sodium fluoride, and mercuric chloride. When the latter preservative is used the process is called Kyanizing. In order to treat to best advantage the wood should be thoroughly seasoned and dry. It is customary to allow it to remain in the preservative

one day for each inch in thickness, and one additional day. A still longer soaking period would probably be advantageous if time would permit. After treatment the timber should be air dried again before using it.

The cost of this treatment will vary with the cost of labor, preservative, character of timber, etc. It is stated on good authority that under pre-war conditions mill construction timber was treated with mercuric chloride for about three dollars per thousand feet.

No definite figures can be given upon the life which may be expected from timber treated by steeping processes on account of the differences in absorption and penetration of preservative and other factors which will affect durability. It can be expected to be much more durable in factory roofs, however, than untreated timber of the same species, and the additional life should well repay the cost of treatment.

More specific directions for the steeping process, especially concerning the use of mercuric chloride, should be obtained before attempting to make treatments. These directions may be had upon application to the Forest Products Laboratory.

Non-Pressure Creosote Treatments

There are several ways* of applying coal-tar creosote with simple appartus. Briefly, they are as follows:

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*Detailed descriptions of them may be found in Farmers' Bulletin 744, "The Preservative Treatment of Farm Timbers," which may be obtained free from the Editor and Chief, Division of Publications, U. S. Department of Agriculture, Washington, D. C.

Brush treatment consists in applying hot creosote to the wood with a brush. The wood should be well seasoned and dry, and the oil should be flooded upon the wood and into all checks and crevices. Two coats are better than one. Relatively little absorption and penetration of oil will be obtained by this treatment, but it should add from two to five years to the life of roof lumber if thoroughly done.

The dipping treatment consists in completely submerging the lumber in a tank of hot creosote for 5 to 15 minutes. It accomplishes the same result as brush treatment, but in a more thorough manner.

Hot and cold bath treatment consists in first submerging the lumber in hot creosote for several hours. and then either allowing the oil to cool down slowly with the wood in it or suddenly plunging the wood into cool oil for several hours. This is a more expensive treatment than any of the previous methods on account of greater costs for labor and apparatus, and greater absorption of preservative. It is also more effective in preventing decay.

Pressure treatments, although the most expensive, are the most effective because they result in the greastest absorption and penetration of preservative. They are suitable for either creosote or water soluble preservatives, such as sodium fluoride and zinc chloride. For roof planking an absorption of 8 to 12 pounds of creosote, or one-half pound of

zinc chloride or sodium fluoride per cubic foot of wood treated should add 20 years at least and probably more to the life of the timber. The cost of treatment can best be obtained by securing quotations from wood preserving companies.*

Characteristics of Preservatives

The various preservatives mentioned have different characteristics which should be kept in mind in considering their use.

Coal-tar creosote is objected to by some insurance companies as a fire hazard. It is not believed, however, that it adds greatly to the inflammability of the wood. It has an odor which may be objectionable in food storage rooms, as some foods are very sensitive to odors. It should not be objectionable to workmen, however, in the small amounts which would be present in buildings. The odor is pleasing to some people. Creosoted wood cannot be successfully painted over, as the oil quickly comes through the paint and discolors it.

If the creosoting is not properly done when the pressure process is used, or a heavy absorption is obtained in the hot and cold bath treatment, some of the oil may exude from the wood and drip. This is commonly called bleeding, and is very

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*The names of companies adjacent to any locality can be obtained from the Secretary of the American Wood Preservers' Association, Mt. Royal Station, Baltimore, Md., or from the Forest Products Laboratory, U. S. Forest Service, Madison, Wisconsin.

undesirable where the drops of oil may cause damage to products such as cotton cloth or paper. It can be largely prevented by steaming the wood in the treating cylinder after the injection of the oil. Allowing the lumber to air dry thoroughly in open piles after treatment will also help. As an additional precaution the under side of the roof may be painted with water glass, or sheathed temporarily with thin untreated lumber. No difficulty from bleeding should be encountered in using dipped or brush treated lumber.

Zinc chloride appeares to attack lead paints, and they do not last very long on zinc treated wood; otherwise zinc treated wood is very desirable.

Sodium fluoride does not attack paint and in most other respects is very desirable. It is colorless and odorless and does not bleed. It is not yet extensively used, however, and it will probably be found very difficult to secure wood pressure treated with this preservative.

The chief disadvantages of mercuric chloride (corrosive sublimate) are its poisonous nature and its corrosive action on steel. The latter prevents the use of steel tanks for treating with mercuric chloride solutions, but neither should discourage the use of this preservative.

Precautions in Using Treated Timber

The effectiveness of treated timber depends upon maintaining a complete envelope of treated wood around the untreated interior of the board. If this treated layer is broken through decay can enter and destroy the untreated interior in spite of the treated outer layer. For this reason it is desirable to have the lumber cut to final dimensions before treatment. Whenever it becomes necessary to cut into treated timber the untreated wood exposed by cutting should be given two coats of creosote or a treatment with some other preservative.

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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
FOREST PRODUCTS LABORATORY
MADISON, WISCONSIN
(In Cooperation with the University of Wisconsin)

DURABILITY OF TREATED AND UNTREATED POSTS AND POLES

By
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NOT FOR PUBLICATION

May 5, 1919.

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DURABILITY OF TREATED AND UNTREATED POSTS AND POLES

The durability of untreated posts or poles of any species is influenced by a great variety of factors. Among the most important of these are the species and quality of wood used, climate, soil, drainage, ground cover, etc. Since different combinations of these factors will occur in different cases, the durability of a given species cannot be expected to always be the same. Any estimates on the durability of post and pole timber must, therefore, be judged with considerable latitude.

In most species of timber the sapwood is very much less durable than the heartwood. The amount of sapwood present, therefore, is an important factor in the durability of untreated wood. Posts or poles cut from dense, close-grown wood are considered more durable than those from more rapidly grown wood. Decayed heartwood, which is often found when the tree is cut, may be a factor in the durability of many species, though a small amount may not have much influence in cedar posts and poles.

Posts or poles which are set in very wet or very dry soils will last longer than those set in soils alternately wet and dry. Those set in cold climates are much more durable than in warm ones. Summer cut timber should be as durable as winter

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cut timber, provided it has been cared for properly after cutting. It is somewhat easier, however, to keep decay from getting into wood during the seasoning period if cut in winter than if cut in the summer.

There is little evidence that seasoning posts or poles which are to be set without treatment increases their durability. In fact, if the timber is held for over one year, deterioration will probably take place and the life will be shortened. Peeling posts or poles before placement is a very important factor, as those set with the bark on deteriorate much more rapidly than those peeled before setting. Large posts or poles will last longer than small ones, as a rule, other conditions being equal. For this reason, in the case of fence posts, the large end should be set in the ground. They should preferably be cut with a bevel in the top to assist in shedding water.

With several of the more durable species, such as northern white cedar, red cedar. catalpa, and locust, it has been stated by one observer that those cut from the open were less durable than those grown in the woods, probably because of greater sapwood and more rapid growth. There is also some evidence that the wood in the center of the tree is less durable than that which is just inside of the sapwood, especially in locust, white cedar, catalpa, and the oaks. This has particular bearing on split fence posts.

The estimates given in the attached table can be considered as approximate only. Individual cases are liable to vary widely from these estimates due to the factors mentioned above.

When posts or poles have been given a preservative treatment, their durability will depend on the amount, kind, and quality of preservative used, the thoroughness of treatment, the kind of timber treated, and the condition of the timber at the time of treatment. Climate is also a factor, but is less important than with untreated posts. The estimates in the attached table are prepared on the basis of a butt treatment with creosote by the open-tank method, and in the case of fence posts a dip treatment of the tops with creosote. For methods of treating fence posts see Farmers' Bulletin 744, "The Preservative Treatment of Farm Timbers," which may be obtained free from the Division of Publications, U. S. Department of Agriculture, Washington, D. C. For poles see Forest Service Bulletin 84, "The Preservative Treatment of Poles." This may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., for 15 cents, stamps not accepted.

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POLES

Estimated Average Life of Treated and Untreated Poles in the United States

(To be used only with explanation given in this circular)

Species	Estimated Average Life	
	Untreated	Treated
	Years	Years
Redwood	12 to 15	20 or over
Cypress	"	"*
Northern white cedar	"	"*
Chestnut	"	16 to 20 *
Western red cedar	9 to 11	20 or over*
White oak	6 to 8	" *
Douglas fir	"	" *
Southern white cedar	"	" **
Longleaf pine	"	" *
Lodgepole pine	2 to 5	" **
Western yellow pine	"	" **
Loblolly pine	"	" **

*Estimate based on butt treatment with creosote by open tank method.

**Estimate based on creosote treatment (8 pounds per cu. ft.) for entire pole.

Not for Publication

POSTS

Estimated Average Life of Treated and Untreated Posts in the United States. (To be used only with explanation given in this circular.)

Species	Estimated Average Life	
	Untreated	Treated**
	Years	Years
Osage orange	Over 15	*
Locust	" "	*
Mulberry	" "	*
Yew	" "	*
Western juniper	" "	*
Catalpa	12 to 15	*
Redwood	" " "	*
Cypress (heart)	"	20 or more
Northern white cedar	"	"
Chestnut	9 to 11	"
Western red cedar	"	"
Southern white cedar	6 to 8	"
White oak	"	"
Longleaf pine	"	"
Douglas fir	"	"
Engelmann spruce	"	12 to 15
Red oak	2 to 5	20 or more
Ash	"	"
Tamarack	"	"
Sitka spruce	"	*
Aspen	"	20 or more
Western yellow pine	"	"
Lodgepole pine	"	"
Alpine fir	"	*
Loblolly pine	"	20 or more
Red gum	"	"

*Not recommended for treatment.

**Estimate based on open tank treatment with creosote with heavy absorption in butt and light absorption in top.

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DURABILITY OF UNTREATED PILING ABOVE MEAN LOW WATER

It has long been recognized that wood constantly saturated with water is not subject to decay. Timber structures below the water level last indefinitely unless affected by some other destructive agent. Although in many harbors the use of untreated or unprotected piling is rendered inexpedient by marine borers, in others not so infested natural or untreated wood is in general use.

In tidal waters portions of piles above mean low tide, although completely immersed for only part of the time, may be practically saturated all the time. Since constant saturation means permanent preservation against decay, the distance to which it occurs above low tide is a question of considerable interest and importance to the designing engineer. The difficulty and expense of cutting off piling at low water, as well as the extra cost and weight of the superstructure if joints must be made at low tide level, are obstacles to economic construction that may well be avoided wherever immunity from decay exists for any distance above this level.

There is little available data as to this zone of immunity. The Forest Products Laboratory is planning a study of the problem by the questionairre method. Preliminary to

the more extensive study planned, nineteen letters have been sent out to various constructing engineers. To date (June 28, 1917) twelve replies have been received. Of these, two stated that the harbors to which reference was made were infested with marine borers; two gave data not directly applicable to the question; one reported no docks on tide water. The information received from the other seven is included in the following summary of data at present available to this laboratory. It will be noted that for each location for which data has been received the mean range of tide and the mean tide level (referred to mean low tide) are given. The relation which the line of permanent preservation bears to mean tide level or half tide may thus be readily observed.

June 28, 1917.

DATA ON DURABILITY OF UNTREATED PILING ABOVE MEAN LOW WATER

Source of information	Location for which report is made	Tide at location named		Data Received
		Mean range	Mean Tide level	
Raymond F. Bennett, Pres. Bennett Contracting Corporation.	Portland, Maine.	8.9	4.5	Wood below half tide will remain sound very many years. For pile driven in solid earth wharf, height of no decay would be higher than for pile standing alone.
Charles W. Staniford, Chief Engineer Dept. of Docks and Ferries.	New York	4.4	2.2	It is safe to lay concrete on piles cut off at range of mean high water for permanency in pier construction.
Richard A. Monks, Vice Pres., John Monks & Sons.	New York	4.4	2.2	Piles can be cut off at half tide without much danger to their decaying. Foundation piles should retain life indefinitely if cut at about half tide or below this level.
G. S. Webster, Director, Dept. of Wharves, Docks & Ferries	Philadelphia Pa.	5.3	2.6	Timber remains sound to an elevation of two feet above mean low tide.
John Meigs, Consulting Civil Engr.	do	5.3	2.6	It has been found safe to place permanent timber as high as 3.5 feet above mean low water.
Engineering News, Vol. XLVII; No. 4; Jan. 23, 1902 p. 70 communication by L.J.Schermerhorn.	Philadelphia Pa.	5.3	2.6	Timber and piles 50 to 100 yrs. old were found sound and free from decay to a height of about 2-1/2 ft. above low water. Engineers do not hesitate to use timber to a height of 2 ft. above mean low water for permanent structures.

DATA ON DURABILITY OF UNTREATED PILING ABOVE MEAN LOW WATER (cont).

Source of information	Location for which report is made	Tide at location named.[1]		Data Received.
		Mean range	Mean tide level[2]	
Communication by L. J. Schermerhorn.	Reedy Island, Del.	5.9	2.9	Piles 80 yrs. of age are sound and free from decay 2-1/2 to 3 ft. above mean low water.
J. E. Willoughby, Chief, Engr. Atlantic Coast Line R. R. Co.	South Atlantic coast	2.7[3]	1.3[3]	Piles cut off 1 ft. above low water will keep sufficiently moist to insure permanent preservation.
Homer Hamlin, City Engr.	Los Angeles Cal.	4.0	2.0	Survey stakes which have been in place for 30 yrs. have been found sound to 1 ft. above sea level.[4]
Foundations of bridges and buildings-By Jacoby & Davis-p.58				Where tide water has access to piles it is often customary to keep the timber of the foundation below half tide rather than below low tide, since it will be kept wet continuously by the rise and fall of the tide.

1. Data taken from General Tide Tables published by the U.S. Coast and Geodetic Survey.

2. Reckoned from mean low tide.

3. Data for the harbor of Wilmington, N. C.

4. Sea level is 0.1 foot higher than mean tide level in this region.

TECHNICAL NOTES

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U. S. FOREST SERVICE
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A complete set or copies of any individual notes may be obtained from the Director of the laboratory without charge.

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No. D-15

A DRYING SCHEDULE FOR AIR SEASONED OAK

The following skeleton drying schedule is recommended for the kiln drying of air-seasoned oak. It must be remembered, however, that no mere formula in itself will insure the perfect drying of wood. The kiln operator must be trained to watch the condition of the lumber and to apply the proper remedies if things start to go wrong.

The schedule was prepared by the U.S. Forest Products Laboratory for 4/4 plain-sawed oak (highland variety) with a moisture content of 15 per cent. This moisture condition would ordinarily be reached in from 9 to 12 months of air seasoning.

Stage of kiln run in hours	Temperature degrees F.	Humidity per cent
1	120	100
6	120	100
12	125	85
24	125	80
36	130	70
48	130	60
60	135	60
72	135	60
84	140	60
96	140	50
108	140	50
120	140	40
144	140	40
156	145	35
168	145	35
180	145	30
192	145	25
Until dry	145	25

After the stock is dry, the temperature should be held at 145 degrees and the humidity raised to 80 per cent. This condition should be maintained for 10 hours in order to balance the moisture content, thus reducing the tendency of the lumber to warp after machining.

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FOREST PRODUCTS LABORATORY

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MADISON, WISCONSIN

No. F-34

SODIUM FLUORIDE AS A WOOD PRESERVATIVE

Tests made years ago at the Forest Products Laboratory indicated that sodium fluoride might be successfully used as a wood preservative, because it had high toxicity, was not injurious to metal, and was convenient to handle. Laboratory tests alone, however, are never sufficient to establish the value of any material as a wood preservative; actual service tests, even though they require years to complete, are also needed.

In order to obtain comparative durability records, the laboratory in 1914 placed sap-pine ties treated with sodium fluoride, together with ties treated with zinc chloride and creosote, in one of the mines of the Tennessee Coal,Iron and Railway Company, at Birmingham, Alabama. Similar service tests were also started at this time on red oak ties placed in the tracks of the Baltmore and Ohio Railway Company.

After five years of service the mine ties which were treated with sodium fluoride have been found in as good condition as those treated with zinc chloride, both showing very little deterioration. The creosoted mine ties apparently were in still better condition, while the untreated ones were in various advanced stages of decay. The red oak railway ties treated with sodium fluoride were practically all sound, as were those treated with zinc chloride, whereas a large percentage of the untreated oak ties had been removed.

Both of these tests, as well as others started later, must continue for a number of years yet before the relative value of the sodium-fluoride treatment for ties and timbers is definitely known.

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FOREST PRODUCTS LABORATORY
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MADISON, WISCONSIN

No. 84

EFFECT OF DECAY ON PAPER-MAKING QUALITIES OF WOOD PULP

Clean groundwood pulp and pulp infected with molds and fungi have been used in recent comparative paper-making trials at the Forest Products Laboratory, Madison, Wisconsin. These trials showed that infected pulp was inferior to clean pulp in the following respects:

The infected pulp produced a very dirty sheet.

It required more sizing than the clean pulp.

It stuck to the couch and press rolls and gave trouble from excessive foaming.

Although groundwood pulp is usually considered too slow, the extreme freeness of the infected pulp caused difficulty in carrying the necessary amount of water on the paper machine to secure a good formation in the finished paper.

Based on the percentage of groundwood, the infected pulp used in the experiments yielded 10 per cent less finished paper than the clean pulp.

The strength of the finished paper was greatly reduced by the use of infected pulp. In a groundwood sulphite furnish, this decrease in strength would necessitate the use of a larger percentage of the more expensive sulphite pulp.

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MADISON, WISCONSIN

No. 85

SHRINKAGE OF VENEER FROM BOILED AND STEAMED LOGS

According to present practice, logs which are to be cut into veneer are either steamed or soaked in hot or boiling water for several hours to soften the wood. The claim is sometimes made that the veneer from boiled logs is likely to shrink and swell less with changing moisture content than the veneer from steamed logs. This point was made the subject of investigation by the Forest Products Laboratory at a plant using both methods of preparing the logs.

Thirty sheets of 1/12-inch rotary-cut birch veneer, 60 inches square, were selected from about six logs prepared in each way. The sheets were carefully measured, passed through a textile drier, and measured again.

The average moisture content of the boiled veneer and that of the steamed before drying were practically the same, being 64.8 and 65.5 per cent, respectively. The average moisture content for both kinds after passing through the drier was 10 per cent, and the moisture contents of all dried sheets were between 7 and 13 per cent.

The shrinkage caused by drying was found to be the same for both kinds of veneer. When the dried sheets were resoaked, they expanded to their original dimensions, and when subjected to a second drying shrank as uniformly as before.

Although these tests were very crude, they indicate that the shrinkage of veneer from boiled and steamed logs is practically the same. The variation is no greater than is found between pieces from different logs which have undergone the same treatment.

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No. 86

SOME REFERENCES TO PUBLICATIONS ON MARINE BORERS

Information on the methods used in combating marine borers, which attack wooden structures in sea water, may be gained from the following publications:

Preservation of Piling Against Marine Wood Borers--U. S. Forest Service Circular No. 128. 1908.

Efficiency of Various Parts of Coal Tar Creosote Against Marine Borers--C. H. Teesdale, in Engineering Record, Sept. 12, 1914.

Preservation of Structural Timber--H.F. Weiss, McGraw-Hill Book Company, 1916.

The Comparative Toxicity of Coal Tar Creosote and Creosote Distillates and of Individual Constituents for the Marine Wood Borer, Xylotrya--L.F. Shackell, in Proceedings of American Wood Preservers' Association, 1915, pages 233-247.

Destruction of Timber by Marine Borers--E. S. Christian and others, published in Proceedings of American Wood Preservers' Association, 1915, pages 296-316.

Marine Borers from the Wood Preservers' Standpoint--L.F. Shackell, Proceedings of American Wood Preservers' Association, 1916, pages 124-131.

Field Tests Made on Oil Treatment of Wood Against Marine Borers--C.H.Teesdale and L.F. Shackell, Engineering News-Record, Nov. 1, 1917, and Railway Age Gazette, Nov. 2, 1917.

Surface Tensions of Wood Preserving Oils as Factors in Protection Against Marine Borers--Proceedings of American Wood Preservers' Association, 1919, pages 113-123.

Other treatises on marine borers, chiefly concerned with their characteristics and habits, are:

Invertebrate Animals of Vineyard Sound. A.C. Verrill, Report of U.S. Commissioner of Fish and Fisheries, 1873, pages 84-94.

The Teredo Navalis. (Shipworm.) Bayley, Transactions of American Society of Civil Engineers, Vol. 3, 1874.

Limnoria. Hewstone, Proceedings of California Academy, Vol. 5, 1874, p. 24.

Shipworms and Pholas. Jeffreys, British Conchology, Vol.3.

Marine Wood Borers. (Shipworms, Pholas, Crustacea.) C.H. Snow, Transaction of American Society of Engineers, 1898, Vol. 40.

Marine Wood Borers of Australasia and Their Work. (Shipworms, Crustacea.) C.Hedley, Eighth Meeting Australasian Association for Advancement of Science, 1901, pages 237-255.

Limnoria. Richardsen, Proceedings U.S. National Museum, Vol.37, No. 1701, 1909, page 95;

Sphaeroma. Ibid. Vol. 38, No.1729, 1910, page 81.

Limnoria. Leach, Edinburgh Encyclopedia, 1914, Vol. 7, page 433.

Marine Wood Borers. (Limnoria, Sphaeroma, Chelura, Shipworms.) C.H. Teesdale, Scientific American Supplement, No. 2031, December 5, 1914, p. 356.

"Die Bohrmuschel (Genus Teredo Linne)." Dr. F. Moll, Naturwissenschaftliche Zeitschrift fur Forst-und Landwirtschaft, Vol. 12, p. 505-563, Nov.-Dec. 1914 This article contains an extensive bibliography.

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No. 87

RELATIVE DURABILITY OF ROCKY MOUNTAIN AND PACIFIC COAST DOUGLAS FIR TIES.

Before the preservative treatment of ties was practised as extensively as at present, the railroad companies using Douglas fir ties held the opinion that the Douglas fir grown in the Rocky Mountains was more durable than that grown on the Pacific Coast. In some of the copper and lead mines in the Rocky Mountains the mountain fir was also considered more durable.

No authentic records are available where coast and mountain fir ties are set in the same locality. Such service records as there are, however, fail to show that the mountain fir has superior lasting qualities. In some instances the mountain fir and in others the coast fir has proved more durable.

Botanically there is no difference in Douglas fir according to the locality in which it grows. Tests made by the Forest Products Laboratory, Madison, Wis., indicate that Pacific Coast fir is on the average somewhat denser and therefore stronger and harder than mountain fir. However, the parts of coast timber usually cut into ties are boxed hearts or wood cut near the piths or from the tops of trees. These are the poorer parts, and coast fir ties therefore generally contain no better wood than mountain fir ties.

The conclusion of the laboratory is that there is practically no difference in the durability of Douglas fir ties cut in the mountains and those cut along the Pacific Coast. It has been observed, though, that the latter receive preservative treatment a little more readily than the former.

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No. 88

A RAPID METHOD OF DETERMINING THE ACTIVE STRENGTH OF SULPHATE COOKING LIQUOR

Experiments at the Forest Products Laboratory, Madison, Wisconsin, on sulphate cooking liquor indicate that the action of NaOH is substantially twice as drastic as that of Na_2S between the ratios of 1 part NaOH to 1 part Na_2S and 4 parts NaOH to 1 part Na_2S.

The active strength of the cooking solution in terms of NaOH is expressed by the equation

$$S = M + N/2$$

where S is the active strength of the solution, M the concentration of NaOH, and N the concentration of Na_2S.

A rapid method of determining the strength of a cooking solution is as follows:-

Add 10 cc of cooking liquor to about 50 cc of water in a porcelain dish. Add 10 cc of a saturated solution of $BaCl_2$. Stir vigorously, and titrate with normal hydrochloric acid to phenolphthalein end point. The number of cubic centimeters is directly proportional to the strength.

This method is the most convenient for use in the digester house, because of its simplicity and the fact that it does not involve a consideration of the ratio of NaOH to Na_2S.

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FOREST PRODUCTS LABORATORY
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No. 89

MOISTURE CONTENT OF WOOD IS INDEPENDENT OF DENSITY

Even after long exposure to the same atmospheric conditions, different pieces of wood do not have exactly the same moisture content. Variations of 2 per cent were recently found in red oak blocks stored under carefully fixed humidity conditions at the Forest Products Laboratory.

These moisture differences, unlike variations in strength, are apparently independent of the density of the pieces. In the laboratory experiments, the variation proved to be as great in blocks of the same density as it was throughout the lot of specimens. Moreover, the range in moisture content was the same in wood of low density as in wood of medium density or high density.

Data on a few representative specimens are given in the accompanying table:

Density of specimen	Average moisture content in percentage of weight oven dry		
	Relative humidity at 80°F.		
	38%	61%	88%
Low			
.519	7.6	11.2	19.4
.527	6.0	10.0	17.4
.536	6.5	11.0	18.2
Medium			
.630	7.7	11.3	18.9
.639	5.8	10.7	18.3
.643	6.8	11.3	19.5
High			
.720	6.4	11.2	19.3
.724	7.4	11.4	19.6
.753	6.1	10.8	18.8
Total Ave.	6.7	11.0	18.8

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No. 90

KILN DRYING OF GREEN HARDWOODS REQUIRES MECHANICALLY PERFECT HEATING SYSTEM

Successful kiln drying of hardwood lumber green from the saw necessitates a very even control throughout the kiln at all times. This means that variations in temperature of even a few degrees or variations in relative humidity of 5-10 per cent are seldom permissible. Such uniformity is possible only when tbe heating coil is properly drained, is relieved of air, and is distributing heat uniformly along its length.

It is the contention of the Forest Products Laboratory, Madison, Wis., that the return-bend heating coil system, by bringing about more uniform distribution of heat in the kiln, enables the operator to obtain quicker and better drying than is possible with the header-coil system, as it is generally installed.

The return-bend heating coil gives a practically even heat distribution under any steam pressure. The header-coil produces different temperatures at either end of kiln, the extent of variation depending on the steam pressure, length of coils, drainage, traps, etc.

Refractory hardwoods require low temperatures, and the lower the temperatures used, the more evident will be the difference in the results obtained with these two types of heating equipment. Under the same careful operation, green hardwoood lumber may be turned out from kilns using the one type satisfactorily dried, and from kilns using the other type checked and over-dried at one end and molded and under-dried at the other end.

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No. 91

RESISTANCE TO DECAY NOW A FACTOR IN CHOICE OF AIRPLANE WOOD

Airplanes in the past have been so short-lived that it has mattered little whether the wood in them was resistant to decay or not. Now with better construction and less accidental breakage of airplane parts,instances are coming to the attention of the Forest Products Laboratory of parts needing replacement because of decay.

The fact is being recognized that many woods in common use for airplanes are not resistant to decay and may be destroyed very rapidly when exposed to unfavorable weather conditions.

Fortunately, there are woods whose value in aircraft has been demonstrated which are highly durable. Among these perhaps the most notable is Port Orford cedar. Two others which in tests made by the laboratory have proved very resistant to decay are southern cypress and California redwood. Douglas fir, white oak, and black walnut stand fairly high in durability. Mahogany and Spanish cedar are reputed to be very durable, but no tests have been made on them in the United States. Spruce,which has been the favorite wood for aircraft,is, unfortunately, appreciably less durable than any of the species mentioned. Likewise basswood, beech, birch, and maple may be classed with the less durable species.

The sapwood of practically all species decays readily. Hence in selecting wood for durability, only the heartwood should be accepted.

In cases where it is not practicable to use a naturally durable wood, the life of the wood part may be prolonged by giving it a preservative treatment. Sodium fluoride is a preservative which may be successfully used on parts that are to be glued. Coal-tar creosote, where its color and odor would not be objectionable, may be used for parts that are not to be glued. Decay in struts, propellers, and some other large members can be prevented by applying a coating of aluminum leaf. This keeps the wood dry, and dry wood does not decay.

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No. 92

WHEN TO HEAT WOOD BEFORE GLUING

Whether a hide glue joint will be strengthened or weakened by heating the wood before gluing depends on the size of the joint. It is assumed, of course, that the work is being done in a glue room that is warm and not draughty, and that the wood itself is at room temperature. Under these conditions, if the joint to be made is of small area, heating the wood is unnecessary. In fact it may be detrimental, for the warmth of the wood will keep the glue thin; and, when pressure is applied, too much glue may squeeze out, leaving a starved joint. It is very easy to apply too much pressure to a small area.

In making glue joints of large size (several inches each way), heating the wood before gluing is of distinct advantage. Many experiments at the Forest Products Laboratory, Madison, Wis., have proved that when the wood in large joint work is not heated, the joints develop full strength only in spots. Weak spots and even open joints are too frequently discovered.

Uniform high strength in joints of large size may be secured by heating the wood in a hot-box for 10 or 15 minutes at 120 to 130 degrees Fahrenheit just before gluing. The heat from the wood prevents the glue from chilling and keeps it liquid until pressure is applied.

It should be rememberered that heating the wood retards the setting of the glue to some extent. In heavy woods, from which the heat escapes slowly, this retarding effect is more marked than in lighter woods. In all species glued cold at the laboratory the time under pressure required to develop full joint strength was less than 8 hours. When heated wood was used, at least 10 hours were required to develop full joint strength in mahogany, and more than 12 hours in red oak and maple.

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No. 93

PULP OUTPUT REDUCED BY LONG STORAGE

How large a loss may be caused by decay in pulp wood through storage was learned in recent observations conducted by the Forest Products Laboratory at a sulphate pulp mill.

Pulp wood which yielded over 3½ tons per digester when used green, after a year's storage yielded only 3 tons. Some which had been stored for from 2 to 3 years yielded only 2½ tons per digester. These losses in production, amounting in the latter case to over 25 per cent, occurred without any compensating reduction in operating expenses. Hence the monetary loss was fully equal to what the lost product would have sold for f. o. b. mill.

Such losses can be largely reduced by so operating the wood yard that the wood is used as nearly in rotation as possible, without allowing any to remain in storage as long as one year.

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No. 94

SUITABILITY OF VARIOUS HICKORIES FOR VEHICLE MANUFACTURE

The principal species of hickory are divided botanically into two groups,-true hickories and pecan hickories. True hickories include shellbark, shagbark, mockernut, and pignut or black hickories. Pecans include bitternut, nutmeg, pecan, and water hickories.

The chief difference between true and pecan hickory, as shown by tests at the Forest Products Laboratory, is in toughness or shock-resisting ability. This is the property which is so valuable in wood handles and vehicle parts. In this property true hickories are far superior to the pecans.

The strength properties of pecan are somewhat in excess of those of oak or maple, and for such articles as handles and buggy spokes, carefully selected pecan is probably to be preferred to either of these two woods. In heavy wagon parts, such as axles, spokes, and felloes, maple and oak are reputed to stay in place better than hickory. Except in case of extreme shortage of maple, true hickory, and oak, it would probably be inexpedient to use pecan hickory for these heavy parts.

The sapwood or white wood of hickory, which is usually preferred by the trade, is the better wood in young, thrifty trees; but in over-mature trees it is inferior to the heartwood. A red color does not necessarily make sound hickory unsuitable for vehicle stock.

A more useful criterion than color is the proportion of summerwood, or nonporous wood, in the annual growth rings. In hickory stock intended for the more exacting uses, the nonporous wood should form at least one-half and preferably three-quarters of the annual ring; and the remaining part should contain very few pores. A further precaution to be observed is that the nonporous part of the annual ring should be hard and flinty.

The best criterion of the strength properties of either true or pecan hickory is the weight of a cubic foot of the dry wood. This weight should not be more than 10 per cent below the average for true hickory; or not less than 45 pounds per cubic foot of oven-dry wood.

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No. 95

THE LENGTH OF WOOD FIBERS

The current supposition that each species of wood has a characteristic fiber length is not borne out by the many thousand measurements which have been made at the Forest Products Laboratory on wood fibers. These measurements show that a greater difference may be found in one tree than exists between the average fiber lengths of different species.

In one Douglas fir disc, for example, the fibers varied from .8 to 7.65 millimeters (.03 to .3 inches) in length, which is a variation of nearly 7 millimeters. On the other hand, the averages of several thousand measurements on Douglas fir and longleaf pine were less than one millimeter apart, being 4.41 and 3.67 millimeters, respectively.

In the first case, 67 per cent of the fiber measurements in one tree fell between 4.5 and 6.5 millimeters, which roughly indicates the meaning of the common term "average fiber length" for the tree or species.

Such data obviously can be of little value for identification purposes, because of the overlapping of the ranges of fiber length in the various species.

Some relations have been observed between the length of fibers and their position in the tree. During the first 20-50 years of growth, the increase in fiber length from the center of a tree outward in any plane is very striking. An approximate maximum having been attained, fiber length, though it may fluctuate somewhat, does not radically change thereafter, even in trees 400 or more years old. Some increase in fiber length occurs also for about two-thirds of the distance from the butt to the top. Within each annual ring the length of the fibers varies, particularly in the conifers, where the early springwood has the longest elements, and the last-formed cells of summerwood the shortest in the ring.

No clearly defined relation has been found between fiber length and the strength of wood. The longer fibers are often found in the weaker material.

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No. 96

RESISTANCE OF GREENHEART TO VARIOUS MARINE BORERS

To what extent greenheart timber resists attack by various kinds of marine borers is being ascertained in a test conducted by the Forest Products Laboratory, Madison, Wis. Six years ago the laboratory placed specimens of this wood in the Gulf of Mexico, in waters infested with pholas, xylotrya, and limnoria.

A recent examination of the timbers showed that, except for a very slight trace of limnoria on the sapwood of one specimen, they had been uninjured by either xylotrya or limnoria, although these borers are very active in this vicinity. All the timbers, however, were severely attacked by pholas. The surfaces of each specimen were covered with burrows from three-fourths to one and one-half inches deep.

How far these burrows will extend with continued exposure remains to be seen, but it is not expected that they will extend much more than two inches. Pholas have not been found to bore very deep in wood. It is evident, however, that greenheart piles for use in pholas-infested waters should be made large enough to allow for reduction in size by pholas attack.

Other information which has been collected by the laboratory on the resistance of greenheart to marine borers in various localities is given in an article by A. K. Armstrong in the Engineering Record, Feb. 5, 1916.

TECHNICAL NOTES

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No. 97

TEARING STRENGTH OF PAPER

That there is no relation between the actual tearing strength or toughness of paper and the values obtained with the commonly-used paper testers is indicated by the results of recent experiments at the Forest Products Laboratory. The method of test, employing a Schopper tensile strength tester, demonstrated that the toughness of paper can be numerically measured, but that the pop test, breaking length, percentage stretch, and number of folds give very little information about this property.

The following table gives the tearing strength of various papers in grams as determined by the laboratory method and the values obtained in the commonly-used tests:

Kind of paper	Wgt. of ream 24x36	Pop test	Breaking length	Stretch	Folds	Tearing strength
	Lbs.	Lbs. per sq. in.	Meters	Per cent	No.	Grams
News sheet	28	8	2915	1.0	1	17
Steamed groundwood (brittle)	34	14	4584	1.5	5	21
Tough kraft (soft feel)	41	44	6670	3.6	3020	80
Hard kraft (tinny feel)	52	38	5320	5.0	556	73
Litho (bleached sulphate)	44	25	4860	2.9	248	83
Bond (all rag)	38	37	5363	5.31	798	88
Ledger (all rag)	87	110	6335	6.1	2436	167

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No. 98

FUEL VALUE OF WOOD

Two pounds of dry wood of any non-resinous species have about as much heating value as a pound of good coal. Speaking in tons and cords, a ton of coal may be taken as the equivalent in heating value of 1 cord of heavy wood, 1½ cords of medium-weight wood, or 2 cords of light wood.

The following table is an approximation of the number of cords of seasoned wood of various kinds needed to give the same amount of heat as a ton of coal, on the basis of 80 cubic feet of wood, with a moisture content of 15-20 per cent, to the cord:

1 cord	hickory	ash	= 1 ton coal
	oak	elm	
	beech	locust	
	birch	longleaf pine	
	hard maple	cherry	
1½ cords	shortleaf pine	Douglas fir	= 1 ton coal
	western hemlock	sycamore	
	red gum	soft maple	
2 cords	cedar	cypress	= 1 ton coal
	redwood	basswood	
	poplar	spruce	
	catalpa	white pine	

Resin gives twice as much heat as wood, weight for weight. Hence such woods as the pines and firs have more heating power per ton than non-resinous woods. The resinous woods in the table are considered as having an average amount of resin (15 per cent).

The fuel value of wood depends in many cases not alone upon its heating power, but also upon such qualities as easy ignition, rapid burning, freedom from smoke, and uniform heat. As a rule soft woods burn more readily than hard woods, and light woods more readily than heavy woods. The pines give a quicker, hotter fire and are consumed in a shorter time than birch; whereas birch gives a more intense flame than oak. On the other hand, oak gives a very steady heat.

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No. 99

EFFECT OF OILS ON STRENGTH OF GLUES IN PLYWOOD

Plywood may be used near machinery and tanks with little likelihood of being dangerously weakened by the action of oil or gasoline on the glue joints. This fact is evident from a test lately completed at the Forest Products Laboratory.

Plywood panels glued with animal, vegetable, blood albumin, and casein glues were immersed for nearly a year in engine oil and gasoline. At regular intervals specimens were removed from the liquids and tested for joint strength. All the glues weakened somewhat during the early part of the test, the animal and vegetable glues more than the casein and blood albumin glues. The total loss of strength in any case, however, was small enough to be negligible under most conditions of service. A glue shear strength of 100 to 125 pounds per square inch is considered sufficient for practically any purpose for which plywood is used. Only in two or three instances did the strength of the casein and blood albumin glues fall below 150 pounds per square inch. Engine oil, castor oil, and gasoline seemed to have practically the same effect on the glue joints.

During the 45 weeks' test, the wood absorbed 60 per cent of its original weight in engine oil and 70 per cent of its original weight in gasoline. The absorption of these oils did not cause any noticeable swelling of the wood.

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No. 100

LIGHT CREOSOTE OILS IN WOOD PRESERVATION

Light creosote oils properly injected into wood apparently will prevent decay until the wood wears out or until it checks so badly that the untreated portions are exposed. Such is the indication of service records collected by the Forest Products Laboratory on railway ties and telegraph poles preserved with low boiling creosotes.

Creosotes used in ties from 25 to 50 years ago were for the most part oils having 50 per cent or more distilling below 235°C., with a residue not to exceed 25 per cent at 315°C. The ties so treated lasted from 15 to 20 years, and failure was traceable in most cases to mechanical wear, such as rail cutting and spike killing. In no case was failure found to be the fault of the preservative.

Of 1558 telegraph poles in the Montgomery-New Orleans line, which were pressure-treated with a light creosote oil, 1049 poles were still sound after 16 years. In 91 per cent of the cases of decay, the fungi had entered the wood through checks and shakes. Representative sections in the Norfolk-Washington line showed that after 17 years service, of the 1614 poles inspected, 1469 were sound, 92 decayed at the top, and 105 decayed at the ground line. The decay at the top was caused chiefly by cutting off the poles. In those decayed at the ground line, the causes of failure, as determined in 88 per cent of the cases, were checks or shakes. Here again as in the ties, the preservative outlasted the mechanical life of the wood.

Unless some other factor than protection from decay is considered important, therefore, there is apparently no need to specify high boiling oils. The important point is that any coal tar creosote which is not extremely low boiling or extremely high boiling will satisfactorily prevent decay, and in the selection of an oil, factors such as price, penetrability, and convenience in handling should receive greater consideration than moderate differences in volatility.

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No. 101

COMPARATIVE VALUE OF TIMBER CUT FROM LIVE AND DEAD TREES

Prejudice exists in certain quarters against the use of timber cut from dead trees, and some purchase specifications insist that only timber cut from live trees will be acceptable. As a matter of fact when sound dead trees are sawed into lumber, and the weathered or charred outside is cut away, there is no method known to the Forest Products Laboratory by which the lumber can be distinguished from that cut from live trees, except that the lumber from dead trees may be partly seasoned when sawed.

All the information available at the laboratory indicates that timber cut from insect or fire killed trees is just as good for any structural purpose as that cut from live trees of similar quality, providing the wood has not been subsequently injured by decay or further insect attack. If a tree stands on the stump too long after it is killed, the sapwood is likely to become decayed or badly infested by wood-boring insects; and in time the heartwood also will be similarly affected. The same thing is true of logs cut from live trees and not properly cared for. Until the wood becomes affected by these destructive agents, dead tree wood should be just as strong and just as durable as sound live tree wood.

In considering the subject it may be useful to remember that the heartwood of a living tree is entirely dead, and in the sapwood only a comparatively few cells are living. Most of the wood cut from trees is dead, therefore, regardless of whether the tree itself is living or not. Such being the case, purchase specifications, instead of providing that material must not be from dead trees, should state that material showing evidence of decay or insect infestation exceeding a specified limit will not be accepted.

No. 102

GAS MASKS IN PULP AND PAPER MILLS

Gas masks of a nose-breathing type with canisters containing special chemicals are used in the digester house of the Forest Products Laboratory to give protection against sulphur dioxide. These masks enable the operator to make repairs under conditions otherwise unbearable and soon pay for themselves in time saved. Masks of this type are reported by the Bureau of Mines to hold up against a 5 per cent concentration of sulphur dioxide for about 15 minutes. When it is realized that 5 parts of sulphur dioxide to one million parts of air can readily be detected, and that at a concentration of 150 parts of sulphur dioxide to one million parts of air the air becomes unbreathable, some idea can be gained of the life of a canister even under adverse mill conditions.

In addition to their use in the sulphite mill, these masks are of great assistance in the bleach room, where they are worn continuously during the mixing of the bleach liquor. Aside from monetary considerations, the increased comfort and safety of the workmen is sufficient argument in favor of the addition of gas masks to the regular mill equipment.

- -

(Not for publication)

Masks for protection against sulphur dioxide may be obtained from any of the following firms:

The Mine Safety Appliance Co.,
Chamber of Commerce Bldg.,
Pittsburg, Pa.

The Industrial Safety Corp.,
102 Fulton St.,
New York City

The La France Fire Engine Co.,
250 W. 54th St.,
New York City

TECHNICAL NOTES
FOREST PRODUCTS LABORATORY
U. S. FOREST SERVICE
MADISON, WISCONSIN

No. 103

HOW TO DISTINGUISH MAHOGANY AND WALNUT FROM RED GUM

In the manufacture of furniture and cabinets a great deal of red gum is used as an imitation of mahogany or Circassian walnut. When red gum is properly finished it can be made to look so much like either of these woods that only by very careful observation can the true be distinguished from the substitute. There is a very distinct difference, however, between red gum and mahogany or walnut. This difference lies in the size of the pores.

In mahogany, Circassian walnut, and black walnut the pores are so large that they can be seen very distinctly on a smoothly-cut surface of the end grain, where they appear as minute openings smaller than pin holes but visible without magnification. On surfaced faces the pores appear as fine grooves, running parallel with the grain. They are even visible through the varnish, appearing as dark lines.

In red gum the pores are much smaller and can be seen only with a magnifying glass.

TECHNICAL NOTES
FOREST PRODUCTS LABORATORY
U. S. FOREST SERVICE
MADISON, WISCONSIN

No. 104

OVERHEATING REDUCES STRENGTH OF ANIMAL GLUE

That long continued heating reduces the strength of animal glue solutions is demonstrated by the following test made at the Forest Products Laboratory.

Solutions of a high grade joint glue and a veneer grade glue were heated for 48 hours at 104, 140 and 176 degrees Fahrenheit, and tested every few hours during this period for strength and viscosity.

In the first 7 hours of heating at 176 degrees the veneer glue lost approximately one-half its joint strength, and the high grade glue joints weakened almost as much. The greatest loss in the strength of the glue joints occurred at this temperature. In the solutions kept at 104 degrees there was a sudden drop in the strength of the joints made with the high grade glue after 31 hours of heating, due possibly to a combination of bacterial and chemical action. The veneer glue joints showed a more gradual decrease at this temperature. The most favorable of the three temperatures tried was 140 degrees, but even at this temperature an appreciable weakening in both glues was noted at the end of 7 hours, and longer heating caused greater loss.

The viscosity of the high grade glue declined more rapidly than that of the veneer glue, but at the end of the heating test the viscosity of the high grade glue still averaged higher than that of the veneer glue.

Covered glue pots were used in this experiment. When open glue pots are used the loss in strength caused by the heat is less apparent, since the loss is compensated to some extent by evaporation of the water. On the other hand, the concentration of the glue solution through evaporation is an expensive means of gaining strength.

TECHNICAL NOTES
FOREST PRODUCTS LABORATORY
U. S. FOREST SERVICE
MADISON, WISCONSIN

No. 105

WHAT IS DRY ROT?

The term "dry rot", the Forest Products Laboratory finds, is applied by many persons to any decay which is found in wood in a comparatively dry situation. Thus loosely used the term actually includes all decay in wood, since wood kept sufficiently wet can not decay.

In the more limited sense in which pathologists use the term, "dry rot" applies only to the work of a certain house fungus called *Merulius lachrymans*. This fungus gains its distinction from the fact that it is frequently found growing in timbers without any apparent moisture supply; in reality it does not grow without moisture and is as powerless as any other fungus to infect thoroughly dry wood. Given moist wood in which to germinate, it is able to make its way a surprisingly long distance in dry timbers, drawing the water it needs from the moist wood through a conduit system of slender, minutely-porous strands.

Wood in the typical advanced stage of dry rot is shrunken, yellow to brown in color, and filled with radial and longitudinal shrinkage cracks, roughly forming cubes. In many instances these cracks are filled with a white felty mass, the interwoven strands of the fungus. The decayed wood is so brittle and friable that it can easily be crushed into powder.

The dry rot fungus is active in nearly every region of this country, in Canada, and in Europe. It is very destructive to factory and house timbers and to logs in storage. Coniferous or soft woods are more commonly infected by it than hardwoods.

TECHNICAL NOTES

FOREST PRODUCTS LABORATORY
U. S. FOREST SERVICE
MADISON, WISCONSIN

No. 106

MAKING WOOD FIRE RESISTANT WITH PAINT

Fire retardent paints are the most practical means so far discovered by the Forest Products Laboratory by which small amounts of wood can economically be made fire resistant. The only other known methods of decreasing the inflammability of wood are to keep it wet, or to inject into it certain chemicals under pressure. These methods, though more effective than painting, are usually either impracticable or too expensive to be considered.

Ordinary calcimine or whitewash has proved in tests to be as fire resistant as any paint covering tried. It is cheap and convenient to use. Although it will not prevent the burning of wood exposed continuously to a high heat, a good coat of calcimine on wood will decrease the danger of a blaze spreading from burning cigarettes, sparks, matches, and similar small sources of fire. Calcimine is, of course, more effective for inside than for outside use.

For exterior use numerous patented fire retardent paints are available. An effective outdoor paint which has been developed at the Forest Products Laboratory consists of linseed oil, zinc borate, and chrome green. This paint has maintained its fire resisting properties through more than three years of exposure to the weather.

TECHNICAL NOTES

FOREST PRODUCTS LABORATORY

U. S. FOREST SERVICE

MADISON, WISCONSIN

No. 107

DRYING PERIODS OF VARIOUS WOODS

Conservative figures to use in estimating the kiln output possible with various woods are given in the following table prepared by the Forest Products Laboratory. Drying time as here given is not limited by the type of kiln, but by the physical behavior of the wood. Any dry kiln in which the circulation is adequate and the temperature and humidity are properly controlled should produce in the time specified material of high quality, free from visible degrade, if not quite equal in strength properties to air seasoned stock.

Approximate time required to kiln dry, under mild conditions, one-inch plain sawed green and partially air dry stock to moisture content of six per cent, based on weight of dry wood

Species	Days drying time	
	Green from the saw	Partially air dry (25 per cent moisture content)
Hardwoods		
Swamp oak	45 to 50	20 to 25
Northern oak	30 to 40	17 to 20
Walnut, Cherry	22 to 30	13 to 15
Mahogany, Beech	16 to 22	9 to 12
Tupelo, Gum	20 to 26	10 to 14
Birch, Ash, Sycamore	15 to 21	9 to 12
Poplar, Basswood, Chestnut, Butternut, Elm, Cherry	8 to 10	4 to 6
Maple, Hickory	17 to 23	9 to 13
Conifers		
Western larch	9 to 12	4 to 6
Cypress, Redwood	10 to 18	6 to 8
Douglas fir, Yellow pine, Incense cedar, Spruce	4 to 6	3 to 4

For stock over 1 inch and not more than 3 inches thick the drying time is proportional to the thickness. For example, 3-inch stock requires 3 times as long to dry as 1-inch stock. Quarter sawed stock requires from 25 to 35 per cent more time to dry than plain sawed. Drying to 10 or 14 per cent moisture content takes from one-fourth to one-third less time than drying to 6 per cent.

TECHNICAL NOTES

FOREST PRODUCTS LABORATORY

U. S. FOREST SERVICE

MADISON, WISCONSIN

No. 108

CHARRING DOES NOT PRESERVE WOOD

Charring is of little value in protecting the butts of fence posts and telephone poles from decay. This is shown by service tests made by the U. S. Forest Products Laboratory on fences of charred and untreated posts of various species. The charred posts proved in these tests to be even less durable than the untreated ones.

Theoretically, an area of charred wood around a post should prevent decay, because charcoal does not decay or encourage the growth of fungi. But the charred area around a post is not usually a solid covering. It is checked through in many places. If posts are seasoned before they are charred, the charring does not reach to the bottom of the season checks which are always present. If green unchecked posts are charred, checks will open through the charred part as the wood seasons. In either case the uncharred center of the post is exposed to fungus infection and will decay as rapidly as any untreated wood.

Charring deep enough to resist decay would undoubtedly weaken a post of ordinary size.

TECHNICAL NOTES

FOREST PRODUCTS LABORATORY

U. S. FOREST SERVICE

MADISON, WISCONSIN

No. 109

PAPER FROM VENEER WASTE

In the wood waste from veneer factories the U. S. Forest Products Laboratory sees considerable raw material suitable for the manufacture of high grades of paper. The cores of many kinds of veneer logs, now used in a large part for fuel, would make excellent pulpwood. In addition, a large part of the clippings and small veneer waste, which amount to 1/5 of the total veneer cut, probably could be turned into pulp stock with profit.

Among the veneer woods whose waste has papermaking possibilities are red gum, yellow poplar, cottonwood, birch, tupelo, basswood, and beech. Many veneer factories cutting these species are already within shipping distance of pulp mills. In certain other cases, veneer factories are so grouped that they might furnish pulpwood enough to warrant the erection of a centrally-located mill. Other economic factors being favorable, such a mill could profitably operate on a daily supply of veneer waste equivalent to 50 cords of ordinary pulpwood. Of course, the construction of a mill should be undertaken only upon the advice of a competent mill engineer after a careful survey of local conditions.

TECHNICAL NOTES

FOREST PRODUCTS LABORATORY
U. S. FOREST SERVICE
MADISON, WISCONSIN

No. 110

SAVING MINE TIMBERS FROM DECAY

Enormous quantities of valuable timbers are being placed in the coal and metal mines of this country without any preservative treatment against decay. That the life of these timbers might be greatly lengthened by the injection of certain chemicals has been proved by the U. S. Forest Products Laboratory in numerous service tests. In 1910 the laboratory installed in an Alabama mine untreated timbers and timbers which had been treated with coal-tar creosote. Ten years later all the untreated timbers had been removed because of decay, while 80 per cent of the creosoted timbers were still sound and none had decayed to a point where removal was necessary. This is only one of the many records obtained by the laboratory which should induce every mining company to install some sort of wood treating plant.

At least three preservatives have been found suitable for mine work. These are coal-tar creosote, zinc chloride, and sodium fluoride. Creosote is the most effective in preventing decay. Timbers thoroughly impregnated with it are likely to resist decay until they are crushed or worn out. Occasional objection is made to the possible fire hazard of creosoted wood, but long experience indicates that the additional fire risk is very small. Zinc chloride and sodium fluoride are odorless, and if anything they tend to reduce the inflammability of wood. They are cheaper than creosote, and although they do not give such permanent protection they greatly increase the life of timbers. Coal-tar creosote may be applied by the brush, dipping, open-tank, or pressure methods. Zinc chloride and sodium fluoride may be injected by the steeping, open-tank, or pressure methods. The cost and effectiveness of the methods of treatment increase in the order given. The saving possible with any of them is so great that it will pay every mine to adopt the use of some preservative on permanently located timbers.

TECHNICAL NOTES
FOREST PRODUCTS LABORATORY
U. S. FOREST SERVICE
MADISON, WISCONSIN

No. 111

DRYING LUMBER WITH SUPERHEATED STEAM

A kiln-drying process which will dry 1-inch softwood lumber green from the saw to 10 per cent moisture content in 24 hours or less has been developed at the U. S. Forest Products Laboratory, Madison, Wisconsin. The novel feature of the process consists in forcing superheated steam at high velocity first in one direction and then in the opposite through the pile of lumber in the kiln. This treatment dries the lumber very uniformly and rapidly with a minimum of checking and warping.

The superheated steam process has been found applicable to Douglas fir, firs of all kinds, western hemlock (not eastern), white cedars (not western red), sugar pine, western yellow pine, and southern yellow pine. It is entirely unsuited for some softwoods on account of collapse.

Drying lumber by this process consumes more steam per thousand feet of lumber than ordinary kiln-drying processes, and is recommended only where economy in fuel is not essential. As it is deleterious for lumber to be exposed for more than 2 or 3 days to the temperatures used, the superheated steam kiln is not adapted to the drying of lumber in thicknesses of more than 2 or possibly 2½ inches. It should be stated, furthermore, that the treatment somewhat reduces the toughness of the lumber, so that where this quality is of prime consideration, as in airplanes and wagons, a low temperature process of drying should be used. On the other hand, the superheated steam method reduces the "working" of the board and the hygroscopicity of the wood and also "fixes" the resin and gum. The effect upon knots as compared with low temperature drying has not been fully determined, but apparently there is not much difference. A slight darkening of the sapwood occurs, increasing with the length of time of exposure, and in periods much over 24 hours the heartwood may darken also.

TECHNICAL NOTES

FOREST PRODUCTS LABORATORY
U. S. FOREST SERVICE
MADISON, WISCONSIN

No. 112

HOW TO TELL WHEN LUMBER IS READY TO BE TAKEN FROM THE KILN

The two things which a dry kiln operator must be able to prove at the end of a kiln run are that his lumber is as dry as is required and that it is free from invisible seasoning stresses which would cause warping when the wood is resawed and shaped into furniture or other products. Neither of these points can be proved by examination of the outside of the lumber. They are easily determined, however, by the following tests which have been devised by the U. S. Forest Products Laboratory, Madison, Wisconsin:

Before the lumber is removed from the kiln, choose a fairly representative board from each truck load of stock. Cut four 1-inch cross-sections (A,B,C,D) from the board at least 2 feet from the end.

Use section A to find the average moisture content of the dried stock. To do this, weigh the section immediately after cutting, on a balance accurate to 1/10 of 1 per cent, and then dry it on a steam pipe or in an oven at 212° F. until it reaches constant weight. The weight lost during this drying is the weight of the moisture which was in the section. Divide the weight of the moisture by the weight of the oven-dry section and multiply by 100. This will give the percentage of moisture in the section and also in the stock in that part of the kiln from which the sample was taken.

For furniture manufacture and other high grade uses, the moisture content of any board in the kiln should not vary by more than 2 or 3 per cent from the final moisture content specified.

Use section B to find out whether the stock is uniformly dry from center to outside. In order to do this the section must be cut apart and the moisture content of the inside and outside found separately. If the stock is 1½ inches or more in thickness, cut the section parallel to its edges to get an outer shell of material 1/4 inch thick. Trim the remaining block equally on all four sides to leave a core 1/2 inch thick. If the stock is less than 1½ inches thick, cut section B so as to get an outer shell and inner core each 1/5 the total thickness of the section. Find the moisture content of each piece by the method used for finding the moisture content of section A.

The moisture content of the inside and outside of the stock should be equalized, by steaming if necessary, to within 2 per cent before the lumber leaves the kiln.

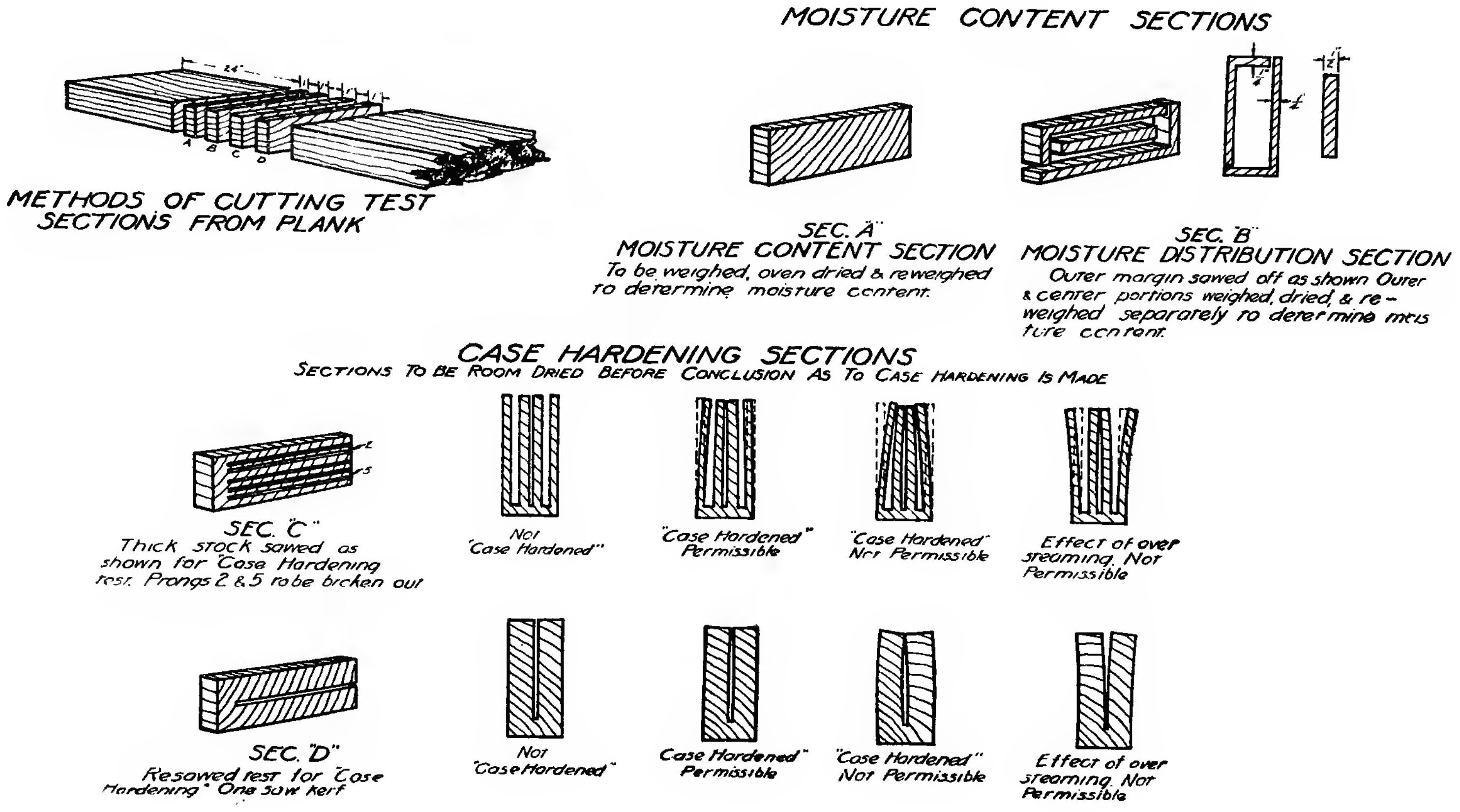
The third and fourth sections, C and D, are for casehardening and moisture distribution tests. Saw section C parallel to the wide faces of the original board to form tongues or prongs, leaving about 1/2 inch of solid wood at one end of the section. If the stock is less than 2 inches thick, make 2 saw cuts; if it is more than 2 inches thick, make 5 saw cuts. From sections having 6 prongs break out the second prong from each side, leaving two outer and two central prongs. From sections having only 3 prongs remove the center prong. In section D saw one central saw kerf to form two prongs. Stand the sections on end in some convenient place in the shop to dry.

Observe carefully the action of the prongs from the moment of sawing. Do they bow in or out or remain straight on the saw? Do they change shape after room drying?

If the prongs remain straight both on the saw and after room drying, the lumber is perfectly seasoned, being free from stresses and uniformly dry throughout.

If the prongs remain straight on the saw but turn in after room drying, the moisture distribution is uneven, the surface being drier than the inside. A short steaming treatment to balance the moisture content should relieve all stresses.

If the prongs turn in on the saw and do not turn out after room drying, the lumber is "casehardened" and is drier outside than inside. Use a steaming or high humidity treatment to moisten and soften the surface. The shrinkage of the outside in redrying should relieve the interior tension, and cause the stresses to disappear.



METHODS OF CUTTING TEST SECTIONS FROM PLANK

MOISTURE CONTENT SECTIONS

SEC. "A"
MOISTURE CONTENT SECTION
To be weighed, oven dried & reweighed to determine moisture content.

SEC. "B"
MOISTURE DISTRIBUTION SECTION
Outer margin sawed off as shown Outer & center portions weighed, dried, & reweighed separately to determine moisture content.

CASE HARDENING SECTIONS
SECTIONS TO BE ROOM DRIED BEFORE CONCLUSION AS TO CASE HARDENING IS MADE

SEC. "C"
Thick stock sawed as shown for "Case Hardening" test. Prongs 2 & 5 to be broken out

Not "Case Hardened"

"Case Hardened" Permissible

"Case Hardened" Not Permissible

Effect of over steaming. Not Permissible

SEC. "D"
Resawed test for "Case Hardening" One saw kerf

Not "Case Hardened"

Case Hardened" Permissible

"Case Hardened" Not Permissible

Effect of over steaming. Not Permissible

TEST SECTIONS FOR MOISTURE CONTENT & CASE HARDENING

TECHNICAL NOTES
FOREST PRODUCTS LABORATORY
U. S. FOREST SERVICE
MADISON, WISCONSIN

No. 113

COLOR OF CYPRESS HEARTWOOD NO INDICATION OF DURABILITY

Southern bald cypress is about the most variable in color of any of our native woods, and in different localities is known as red cypress, yellow cypress, white cypress, and black cypress. There is a rather prevalent belief that cypress with dark colored heartwood is the most durable, but the opinion of the U. S. Forest Products Laboratory is that as far as durability is concerned the color of the wood makes very little difference. In service records obtained by the laboratory, any difference in the length of service of red cypress and yellow cypress appears to be due entirely to a difference in the amount of sapwood in the timbers. Cypress trees with light colored heartwood usually have more sapwood than those with dark colored heartwood, and sapwood is not resistant to decay.

The important thing if durability is desired appears to be to select the heartwood of cypress regardless of its shade.

TECHNICAL NOTES
FOREST PRODUCTS LABORATORY
U. S. FOREST SERVICE
MADISON, WISCONSIN

No. 114

WATER SOLUBILITY A NECESSARY PROPERTY OF WOOD PRESERVATIVES

That any substance to be an effective wood preservative must be soluble in water at least to the extent of producing a toxic water solution is the basis of a theory now being developed at the U. S. Forest Products Laboratory. It would seem reasonable to expect that any material which is poisonous enough to kill an organism of any kind must necessarily be soluble in the body fluids of that organism; and the chief body fluid of timber-destroying fungi and wood borers is water. With very poisonous materials this solubility need not be great; in fact, 1 part in 1,000,000 may be sufficient if the material is poisonous enough.

Wood preservatives now in use are of two distinct types - inorganic salts, such as zinc chloride, which are very soluble in water; and oils, such as the creosotes, which are generally considered to be insoluble. The solubility of creosote is usually considered so slight as to be neglected, but experiments indicate that certain constituents of creosote are sufficiently soluble in water to make it poisonous for wood destroyers. Creosote oil may, therefore, be considered as consisting of two groups of compounds, one of these being sufficiently soluble in water to render it toxic. the other insoluble in water and hence not toxic. The non-toxic oils act as a reservoir for the toxic oils and feed them slowly to the moisture in the wood.

The difference between oil preservatives and inorganic salt preservatives, as far as this theory is concerned, is in their method of retaining the reserve supply of poison. Zinc chloride has no reserve supply, all the material being soluble in the usual amount of moisture present in air-dry wood. Sodium fluoride may have a reserve supply in the form of solid crystals, if applied in a saturated solution. Creosote oil may have a considerable reserve supply stored in the oil itself, this supply being fed to the wood as needed.

TECHNICAL NOTES

FOREST PRODUCTS LABORATORY
U. S. FOREST SERVICE
MADISON, WISCONSIN

No. 115

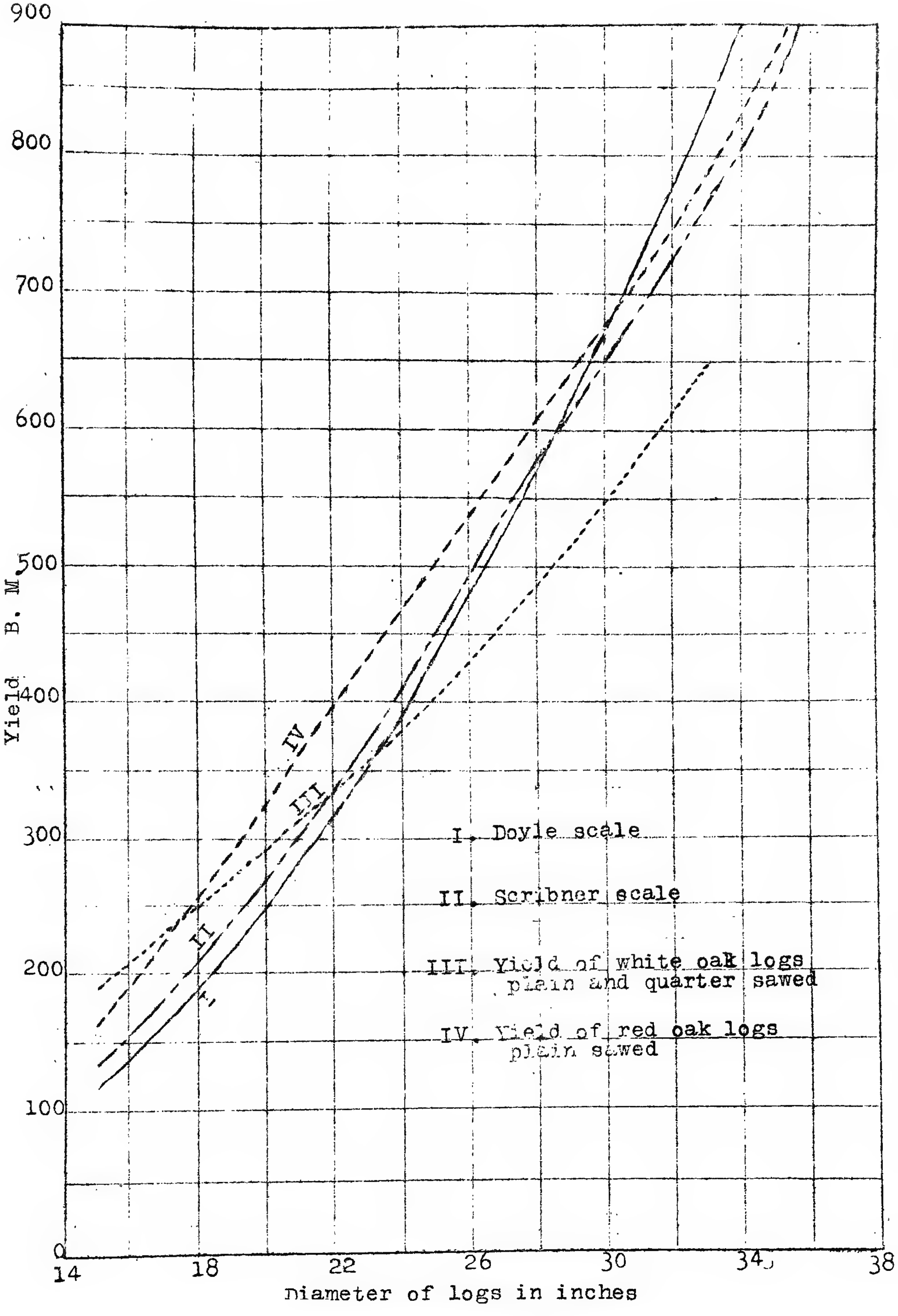
CHECKING THE DOYLE AND SCRIBNER LOG SCALES

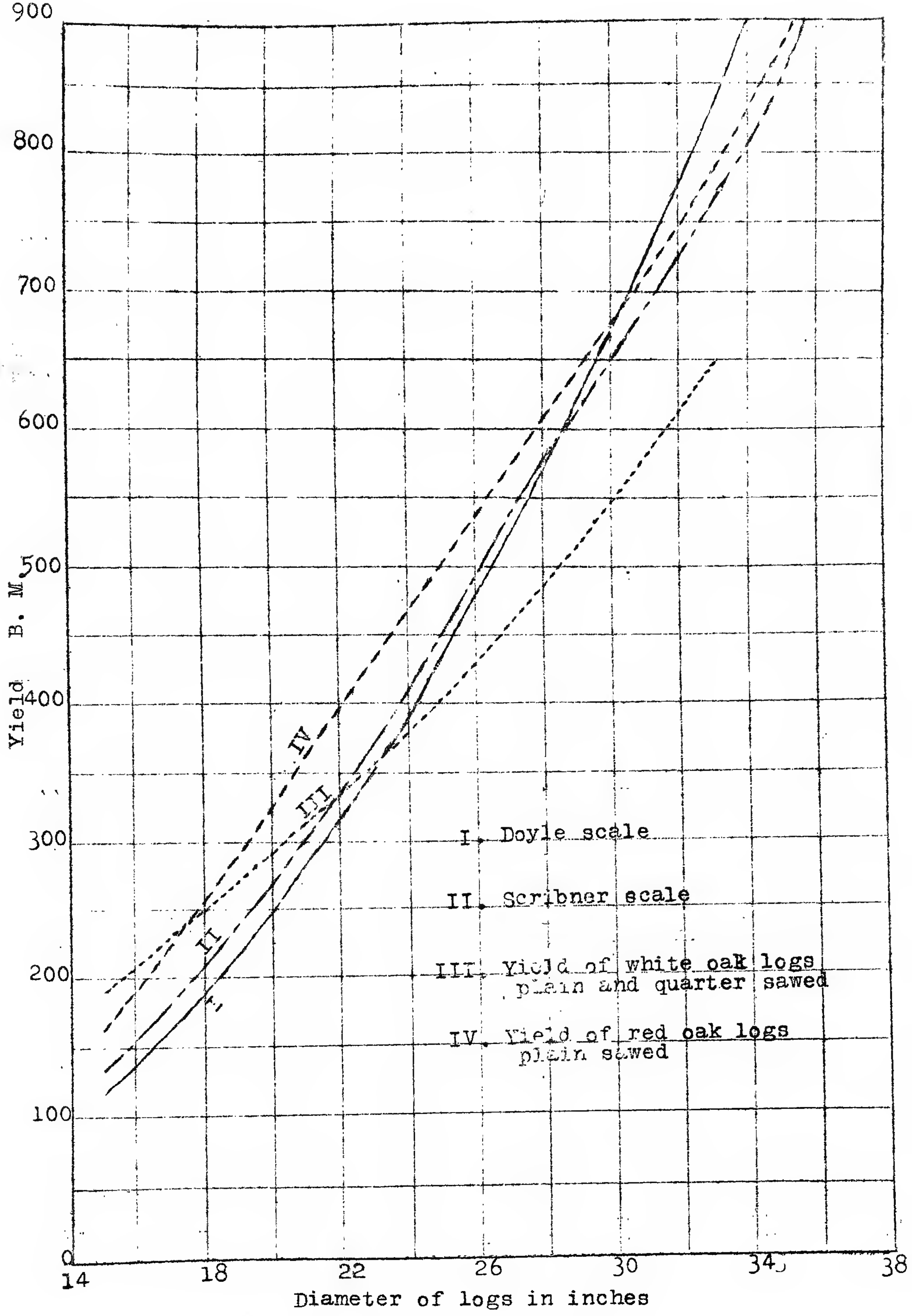
An opportunity for checking the Doyle and Scribner log scales with the net lumber tally for logs of different diameters was afforded during a mill scale study conducted at Proctor, Arkansas, by the U. S. Forest Products Laboratory. The mill was a single band cutting red and white oak. The red oak logs were plain sawed, except that the last quarter of exceptionally good logs was quarter sawed. The white oak logs were plain or quarter sawed to the best advantage - that is, logs up to 22 and 24 inches were plain sawed and larger logs quarter sawed. Approximately 90 per cent of the lumber was 1-inch stock, 5 per cent 2- and 3-inch stock, and the remainder crossties and small timbers.

The net lumber tally is plotted against both the Doyle and Scribner scales in the accompanying chart. As will be seen, the Doyle scale gives an exceptionally large overrun for small logs. The Scribner scale is more accurate than the Doyle scale for small logs but often gives too small results for large logs.

A combined Doyle-Scribner scale using the Doyle scale on logs up to 28 inches and the Scribner scale on logs 28 inches and over would give the largest possible overrun for both large and small logs.

The overrun or underrun will probably never be the same in any two mills, because of variations in thickness of saw kerf, thickness and width of material sawed, percentages of the different sizes, quality of the log with reference to defects, efficiency of labor, and like factors.


900
800
700
600
500
400
300
200
100
0
Yield B. M.
14
18
22
26
30
34
38
Diameter of logs in inches
I
II
III
IV
I. Doyle scale
II. Scribner scale
III. Yield of white oak logs plain and quarter sawed
IV. Yield of red oak logs plain sawed


900
800
700
600
500
400
300
200
100
0
Yield B. M.
14
18
22
26
30
34
38
Diameter of logs in inches
IV
III
II
I
I. Doyle scale
II. Scribner scale
III. Yield of white oak logs plain and quarter sawed
IV. Yield of red oak logs plain sawed

TECHNICAL NOTES
FOREST PRODUCTS LABORATORY
U. S. FOREST SERVICE
MADISON, WISCONSIN

No. 116

HOW TO TELL BIRCH, BEECH, AND MAPLE APART

Birch, beech, and maple are very similar in appearance, and have approximately the same weight. Hence it is comparatively easy to mistake one of them for another. A method which anyone can use to distinguish them is suggested by the U. S. Forest Products Laboratory. The method makes use of the relative width of the pores and medullary rays in the three woods.

If the end grain of birch, beech, or maple is cut smooth with a sharp knife and examined with a hand lens, the pores will be seen as tiny holes distributed fairly evenly over the surface, and the medullary rays will appear as narrow lines of a different shade running at right angles to the growth rings.

In beech some of the rays are very distinct even without a lens. The large rays are fully twice as wide as the largest pores.

In maple the rays are less distinct, and the largest are about the same width as the largest pores.

In birch the rays are very fine, invisible without a lens. The pores are several times larger than the rays, usually being visible to the unaided eye as minute holes on the end grain and as fine grooves on dressed faces of the board. The pores in birch are considerably larger than the pores in beech or maple.

The appearance of the medullary rays on a "quartered" surface is also distinctive. Here they appear in beech as distinct "flakes", the largest being between 1/16 and 1/8 inch in height when measured along the grain of the wood. In maple they are considerably smaller, rarely attaining a height of 1/16 inch. In birch they are comparatively inconspicuous.

TECHNICAL NOTES
FOREST PRODUCTS LABORATORY
U. S. FOREST SERVICE
MADISON, WISCONSIN

No. 117

BOOK PAPER FROM SOUTHERN PINE AND RED GUM

The possibility of using southern pine and red gum for the production of high-grade book and magazine paper has been demonstrated in recent trials at the U. S. Forest Products Laboratory, Madison, Wis. Book paper requires for its manufacture two kinds of woods - a long-fibered wood, such as spruce, to impart strength, and some short fibered hardwood to give the formation, finish, opacity, and other printing qualities. The southern pines are long-fibered woods, excellently suited for the manufacture of wrapping paper and fiber board, but their pitch content and the difficulty of bleaching them have heretofore been obstacles in the way of their use for white paper. These obstacles, it has been shown, can be overcome in a large measure by proper cooking conditions and improved bleaching methods. Red gum is typical of many southern hardwoods that might be used with the pines in the manufacture of the better grades of printing paper.

The laboratory experiments indicate that one cord each of loblolly pine and red gum are capable of yielding one ton of paper, at a cost which should allow a good profit under prevailing conditions.

The utilization of the southern pines for book paper would spread the burden of the pulpwood supply over considerable territory which is favored with a large annual growth of timber. In fact, although the bulk of the standing timber of the United States is in the Far West, the bulk of the annual growth is now in the South. Pines and hardwoods are distributed throughout the southern states in proportions well suited for the manufacture of book paper, and the forests are near the centers of paper consumption as well as the supplies of coal, chemicals, and other necessary raw materials.

Additional information and samples of the paper made in the trial runs of pine and red gum may be obtained from the Forest Products Laboratory on request.

TECHNICAL NOTES
FOREST PRODUCTS LABORATORY
U. S. FOREST SERVICE
MADISON, WISCONSIN

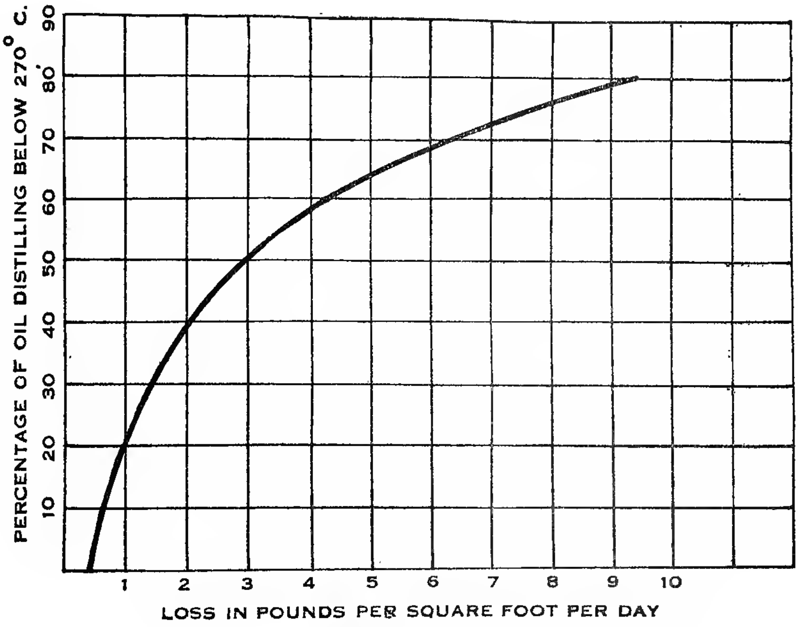
No. 118

LOSS OF CREOSOTE BY EVAPORATION FROM OPEN TANKS

The amount of creosote lost through evaporation in open tank treatments has been shown in experiments at the Forest Products Laboratory to be in proportion to the area of the exposed surface and the volatility of the oil. At the treating temperature of 195° Fahrenheit, the loss of creosote in pounds per square foot per day may be computed from the equation,

$$\text{Log } L = .0165\ V - .347$$

in which L is the loss in pounds per square foot of exposed surface, and V the percentage of the creosote distilling below 270° centigrade. Or the loss may be found without computation from the curve of this equation given below.



The equation and curve given here are applicable only when the temperature of the treating bath is in the neighborhood of 195° Fahrenheit. At higher and lower temperatures, constants other than .0165 and .347 should be used, and these constants have not yet been determined.

TECHNICAL NOTES

FOREST PRODUCTS LABORATORY

U. S. FOREST SERVICE

MADISON, WISCONSIN

No. 119

STRENGTH OF SOUTHERN PINE AND DOUGLAS FIR COMPARED

There is little difference between the strength of the southern pines and that of Douglas fir from the Pacific Northwest, tests made at the United States Forest Products Laboratory show. True longleaf yellow pine averages heavier, stronger, and tougher than Douglas fir. True shortleaf pine averages heavier and tougher than the fir, but is about equal to it in strength as a beam or post. Loblolly pine, though averaging heavier than the fir, is somewhat weaker. The difference in strength between any of these pines and Douglas fir, however, is not so great but that low density pieces of the one species are weaker than the average for the other species.

As far as strength properties are concerned, the choice between any two lots of southern pine and Douglas fir will depend upon the grade and density of the timber composing each lot. The Rocky Mountain type of Douglas fir averages considerably weaker than the Pacific Coast type.

TECHNICAL NOTES

FOREST PRODUCTS LABORATORY
U. S. FOREST SERVICE
MADISON, WISCONSIN

No. 120

YIELDS OF ALCOHOL FROM WOOD WASTE

Softwood lumber mill waste can be made to yield twenty gallons or more of 95 per cent alcohol per ton, and hardwood waste about half as much. Some actual yields obtained by the U. S. Forest Products Laboratory, Madison, Wisconsin, from the waste of various woods are given in the following table.

SOFTWOOD WASTE

Kind of wood	Percentage of wood convertible into sugars	Percentage of sugars fermentable	Gallons of 95% alcohol from 1 ton of wood
White Spruce	23	71	25.8
Longleaf Pine	23	72	25.1
Red Spruce	22	72	24.0
Norway Pine	25	66	23.4
Idaho White Pine	21	74	23.4
Western Hemlock	21	77	23.0
Montana White Pine	20	75	22.0
Lodgepole Pine	21	67	21.8
Sugar Pine	20	66	21.5
Douglas Fir	21	67	20.7

HARDWOOD WASTE

Kind of wood	Percentage of wood convertible into sugars	Percentage of sugars fermentable	Gallons of 95% alcohol from 1 ton of wood
Silver Maple	20	47	14.1
Birch	20	46	12.9
White Oak	17	50	12.4
Red Gum	20	38	11.0
Sycamore	18	38	9.7
Hard Maple	18	34	9.1
Red Oak	19	30	8.1
Cottonwood	18	30	7.2
Slippery Elm	16	26	6.0

The manufacture of industrial alcohol is at present about the only feasible method of utilizing lumber mill refuse on a large scale. An alcohol plant with a

daily supply of 180 tons of wood can produce 3600 gallons of alcohol at a cost, under present conditions, of approximately 25 cents a gallon. The success of plants now in operation justifies a serious consideration of this process by mills having a large quantity of waste. A descriptive pamphlet including estimates of plant requirements and recent cost data on the manufacture of alcohol from wood is obtainable from the Forest Products Laboratory on request.

TECHNICAL NOTES

FOREST PRODUCTS LABORATORY
U. S. FOREST SERVICE
MADISON, WISCONSIN

No. 121

AUTOMATIC CONTROL OF HUMIDITY IN SHOPS

Devices for controlling humidity in shops are of three types. The first are makeshifts, such as wet sawdust strewn on the floor, troughs of running water at the sides of the room, or simply an ordinary sprinkling can. Such crude devices are not in any sense self-regulating, and even with the most careful personal attention produce only haphazard results. The sprinkling-can type of humidifier has been in use for hundreds of years and is of interest chiefly because it shows that the need for air-conditioning apparatus in many industrial plants has been recognized for a long time. A second class of humidifiers includes those that are capable of increasing the moisture in the air up to the point for which they are set, but cannot decrease it. When the weather forces the humidity above the desired point, such instruments remain inactive. Few instruments of this type attempt any control of the temperature. A third type of conditioning apparatus is that which is able to hold the atmosphere in a room at a constant temperature and humidity irrespective of outside conditions.

One of the few instruments which absolutely control both the temperature and the humidity of the air is that developed at the Forest Products Laboratory, Madison, Wisconsin. For several years this apparatus has maintained in the laboratory wood-parts storage rooms the typical climatic conditions found in various parts of the United States, ranging from the hot, moist climate of the South to the cold, dry climate found in the mountain regions. The same type of instrument also keeps the woodworking rooms at the laboratory at uniform temperature and humidity year in and year out, with the result that the wooden articles manufactured there give the minimum amount of trouble afterwards from warping and checking, and the shop conditions are healthful and comfortable to the highest degree. These instruments have required very little personal attention since they were installed.

The principle upon which the laboratory automatic humidity-control apparatus works is that of cooling the air to the dewpoint temperature for the desired atmospheric

condition, saturating it with moisture at that point, and then heating it without addition of moisture to the required room temperature. For any given room temperature it is possible to get any humidity desired, simply by choosing the temperature at which the air is saturated.

The apparatus consists of a small cabinet, or chamber, through which the air is drawn as often as it needs to be conditioned. The conditioning chamber contains water sprays whose temperature is kept constant by a mixing valve. These sprays suck in the air by their own action, cool it to the temperature at which it should be saturated, and give it all the moisture it can hold. As the air leaves the chamber it is heated to room temperature by coils, whose steam supply is controlled by a thermostat located in the outlet. Thus when the air is drawn into the chamber it may be too hot or too cold, too moist or too dry, but the apparatus automatically humidifies or dehumidifies it and brings it to the correct temperature before allowing it to pass again into the room. Both in the storage rooms, where the air needs conditioning very infrequently, and in the workrooms, where it is completely changed every ten minutes, the recording instruments show that the atmospheric conditions have varied to only a slight extent throughout a three-year period.

This method of air conditioning was developed primarily for woodworking shops and wood gluing, finishing, and drying rooms. It is adaptable, however, to numerous other industrial plants, including textile mills and chemical, foodstuff, and tobacco factories, in which close control of atmospheric conditions would be beneficial to both the material being manufactured and the health of the employes. It is practicable wherever there is a supply of cold water and steam heat.

Drawings of the apparatus and further details concerning its installation and operation may be had on application to the Forest Products Laboratory

TECHNICAL NOTES

FOREST PRODUCTS LABORATORY

U. S. FOREST SERVICE

MADISON, WISCONSIN

. No. 122

COMPARISON OF FIVE DIFFERENT TYPES OF GLUE

Table prepared by Forest Products Laboratory

Particular compared	Animal glue	Casein glue	Vegetable glue	Blood glue	Liquid glue
Source	Hides, bones, horns, etc.	Casein from milk	Cassava starch	Dried blood	Animal glue or fish parts
Cost per lb. 1920	25-42 cents	16-20 cents	10-12 cents	20 cents	$1-$5 per gal.
Spread in sq. ft. per lb.	25-35	35-55	35-50	30-100	No data
How mixed	Soaked in water and melted	Mixed cold with rapid stirring	Mixed with alkali and cold or hot water	Mixed cold	No preparation
How applied	Warm with brush or mechanical spreader	Cold with brush or mechanical spreader	Cold with mechanical spreader, not by hand	Cold with brush or mechanical spreader	Cold or warm usually applied by hand
Temperature of press	Cold, or with hot cauls	Cold	Cold	Hot	Cold
Strength (in shear test)	High grades stronger than strongest woods	Equal to medium grade animal glue	Equal to medium grade animal glue	High strength in plywood. Not used for joint work	Best grades equal to medium grade animal glue
Water resistance	Low	High	Low	High	Low
Chief uses in woodworking	For strong joint work	For water resistant plywood or joint work	For veneer work because of cheapness	For water resistant veneers	For repair work and small articles

TECHNICAL NOTES

FOREST PRODUCTS LABORATORY
U. S. FOREST SERVICE
MADISON, WISCONSIN

No. 123

REDUCE PULPWOOD DECAY BY PROPER STORAGE

Wood storage conditions at pulp mills are the primary causes for pulp losses as high as 400 pounds per cord of wood, and inestimable losses through poorer quality of paper. Recent investigations by the U. S. Forest Products Laboratory, Madison, Wisconsin, have shown that the wood yards of many mills are littered with rotting bark and debris which serve as sources of infection for the fresh wood. Pulp wood is generally piled directly on the ground, which is usually poorly drained and overgrown with weeds, thus preventing the necessary circulation of air. The wood is not used in rotation, and some of it remains in the piles for several years. These conditions must be corrected before the mills can expect to control the decay problem.

The chief points recommended by the laboratory in reforming the present practice of pulpwood storage are:

> Ship pulp logs as soon as possible after cutting, to prevent their lying in the woods where high moisture content and growing vegetation tend to cause infection and decay.
>
> Peel logs, if possible, as this prevents borers from attacking the wood, and also hastens air drying.
>
> Drain and care for storage yards, so as to reduce the soil moisture as far as possible; cut weeds to permit better ventilation. Filling in the yard with cinders will give good drainage and keep down weeds. The yard should never be placed on barker waste.
>
> Do not rick wood directly on the ground. The best procedure is to pile it on stringers supported by concrete piers or creosoted wood blocks. The stringers should be pressure-treated with coal-tar creosote. The piers or blocks should be high enough to raise the stringers at least 12 inches off the ground to allow for ample ventilation.

If ground is available, pile so that the full length of the pile is exposed to the prevailing winds. Never place the piles less than three feet apart.

Mark each pile of logs with the date it was received and, if possible, the age of the wood. Use up the wood in rotation.

Upon removal of a pile of wood, clean up the debris and burn it, lest it become a source of infection for new wood. All infected skid logs should be removed.

Where timber is placed in conical piles by conveyors, a possible remedy may be to keep the wood saturated with water by means of an overhead sprinkler system delivering the minimum amount of water necessary to keep the surface of the pile wet. Wood saturated with water will not rot because there is not enough air within the timber to allow the fungi to grow. Whether it is commercially possible to wet the piles down sufficiently and maintain them in this condition must, however, be demonstrated by actual test.

TECHNICAL NOTES
FOREST PRODUCTS LABORATORY
U. S. FOREST SERVICE
MADISON, WISCONSIN

No. 124

MATERIALS USED IN DRY KILN CONSTRUCTION

Any of the ordinary building materials– wood, brick, tile, or concrete– may be used in the construction of a dry kiln. The choice between them will depend upon the relative importance of the first cost, maintenance, and fire hazard. The following comments on each type are based on the experience of the U. S. Forest Products Laboratory.

Where insurance rates permit, a well-built wood kiln is very satisfactory, wood being a very good insulator, easily repaired, and cheaper than the other materials. The chief objection to the use of wood, aside from fire risk, is its tendency to swell and shrink with alternate moist and dry conditions, causing more or less working of the frame and loosening of nails. All lumber should be thoroughly seasoned. Fir, Douglas fir, yellow pine, redwood, cypress, and similar woods with low shrinkage rates should be used for sheathing and sills. For frame timbers any good straight-grained material is suitable. The sheathing should be shiplap laid horizontally and nailed twice at each stud, in the middle and at the bottom of the board. Outside walls should be sheathed on both sides or sheathed inside and plastered outside. They should also be insulated with a good moisture-proof, heat-resistant insulator. The ordinary quilt insulations sewed between so-called waterproof paper have not proved satisfactory in dry kiln construction. Walls should be painted on the inside with asphaltic paint. Where lumber is plentiful, crib or laminated construction may be used, the walls being built up of 2 by 6 inch planks laid flat, and the roof of similar material laid tight together. If the planks are well seasoned and well manufactured, this form of construction permits very little heat loss; but if the lumber is low grade and knotty, a tight, weather-resistant construction is extremely difficult to obtain. The shrinkage of the walls is excessive, and causes considerable trouble at door jambs and where pipes pass through the walls.

Brick or hollow tile is procurable almost everywhere, and where permanency is desired is usually more satisfactory than wood. The brick or tile should be hard

burned. The walls should be laid up in tempered or cement mortar. Unequal expansion in the exterior walls, caused by the difference in temperature of the outer and inner faces, is almost certain to create numerous small cracks, which should be painted up with an elastic cement rather than mortar. A kind of tile should be chosen that has openings running horizontally rather than vertically in the wall. The tile should be scored for plastering. Both sides of tile walls should be plastered with cement mortar. When brick, tile, or concrete kilns are over 50 feet long, it is advisable to build both the exterior and interior walls 12 inches thick, particularly if fireproof roofs are used.

Walls of monolithic concrete or of concrete blocks are highly absorbent of moisture unless thoroughly waterproofed. It is very difficult to hold a high humidity within a kiln whose walls absorb moisture readily. The heat loss through such walls is also very great.

U. S. Department of Agriculture, Forest Service

FOREST PRODUCTS LABORATORY

In cooperation with the University of Wisconsin

MADISON, WISCONSIN

List of Publications on

TIMBER PHYSICS

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LIST OF PUBLICATIONS ON TIMBER PHYSICS

FOREST PRODUCTS LABORATORY
MADISON, WISCONSIN

Mimeographed Circulars

Copies of the following mimeographed circulars will be sent free upon application to the Director, Forest Products Laboratory, Madison, Wisconsin, as long as the supply lasts.

"The Improved Water Spray Humidity Regulated Dry Kiln"
"How to Measure Conditions in Seasoned Lumber"
"Specifications for Kiln Drying Black Walnut Gun Stocks"
"Supplemental Instructions to Accompany Specifications for Kiln Drying Black Walnut Gun Stocks"
"Supplemental Instructions for Drying Less Difficult Species Such as Ash, Mahogany, and Spruce"
"Brief Synopsis in Regard to the Kiln Drying of Oak for Wagon Stock; Including Mention of Hickory, Elm, Birch, and Maple"
"The Handling, and Storing, and Care of Spruce Airplane Stock"
"The Care of Airplane Wood"
"Recording Thermometers"
"Discussion of Specifications for Kiln Drying Wood for Airplane Uses"
"How to Determine Relative Humidity"
"Steaming of Lumber During Kiln Drying"
"Methods of Determining Casehardening and Stresses in Lumber"
"Drying Schedules, Numbers one to Eight, With Explanatory Instructions Recommended for Kiln Drying One-Inch Hardwoods for Furniture and General Interior Use"
"Relation of Moisture Content of Wood to the Humidity in the Surrounding Air"
"Methods of Determining Moisture Content of Wood and Use of Kiln Samples"
"The Kiln Drying of Red Gum"
"Brain Work in Kiln Operation"
"Experiments in Kiln Drying Southern Yellow Pine"
"Kiln Drying Specifications for Lumber"
"The Phenomena of Drying Wood"

"Manual of Design and Installation of Forest Service Water Spray Dry Kiln"
"Notes on the Operation of the Forest Service Water Spray Dry Kiln and Theoretical Considerations of Heat Relations"
"Drying of Plywood Panels"
"Eucalyptus Lumber"
"Shrinkage of Interior Trim: Its Cause and Prevention"
"How to Distinguish Douglas Fir From Sitka Spruce"
"The 'Grain' of Wood with Special Reference to the Direction of the Fibers"
"Key for the Identification Without the Aid of a Hand Lens of Native Woods Used for Chairs and Other Furniture"
"Key for the Identification Without the Aid of a Hand Lens of Woods Used for Box and Crate Construction"
"How to Separate Black Ash from Commercial White Ash Lumber"
"The Identification of True Mahogany and Certain So-Called Mahoganies"
"Factors Affecting the Strength of Wooden Members"
"Short list of Books on Wood"
List of Government Publications on Wood and Trees Each Covering a Large Number of Species
Publications Recommended for Dry Kiln Operators
Publications Recommended for Wood Inspectors

Technical Notes

D-1 Steaming of Vehicle Stock During Kiln Drying
D-2 How to Distinguish Douglas Fir from Sitka Spruce Lumber
D-3 Built-up Artificial Limb Blanks
D-4 Circulation and Piling in the Dry Kiln
D-5 Correct Moisture Content of Lumber
D-6 Government Publications of General Interest on Woods and Trees
D-7 Quarter-Sawed Oak Chair Posts at Plain-Sawed Prices
D-8 Coatings that Prevent End Checking
D-9 Flat Panels and No Surface Checks by Maximum-Humidity Method
D-10 Piling Oak Dimension To Reduce Season Checks
D-11 How to Distinguish Black Ash from Commercial White Ash Lumber
D-12 Uneven Coatings on Wood Cause Warping
D-13 Casehardened Lumber and Warped Products
D-14 How to Accomplish Rapid Kiln Drying
D-15 A Drying Schedule for Air-Seasoned Oak

Papers Prepared by the Forest Products Laboratory and Published in Proceedings of Societies; Trade, Technical and Other Journals

Kiln Drying

Title	Author	Where published	Date
Shrinking and Swelling of Wood	Koehler, Arthur	Furniture Manufacturer and Artisan	Mar. 1920
Preventing Shrinkage of Interior Trim	Teesdale, L. V.	Building Age	July, 1919
		American Architect	July, 1919
		House Beautiful	Sept. 1919
The Phenomena of Drying Wood	Tiemann, H. D.	Jour. of Franklin Institute	July, 1919
Kiln Drying Specifications for Lumber	Tiemann, H. D.	Hardwood Record	June, 10, 1919
Proper Care of Airplane Wood	Hallauer, F. J.	Timberman	June, 1919
Brain Work in Kiln Operation	Sweet, C. V.	West Coast Lumberman	June 1, 1919
		Hardwood Record	May 10, 1919
How to Dry Red Cedar to Avoid Collapse	Tiemann, H. D.	West Coast Lumberman	Mar. 15, 1919
Experiment in Kiln Drying Southern Yellow Pine	Imrie, J. E.	Am. Lumberman	Sept. 1, 1917
		St. Louis Lumberman	Sept. 1, 1917
		Lumber Trade Journal	Sept. 1, 1917
Measuring Conditions in Seasoned Lumber	Imrie, J. E.	So. Lumberman	Mar. 10-'17
		Hardwood Record	Mar. 10-'17
		Am. Lumberman	Mar. 10-'17
		Lumber Trade Journal	Mar. 15-'17
*Relation of Moisture Content and Drying Rate of Wood to Humidity of Atmosphere	Koehler, Arthur	American Lumberman	July 12, 1919

Title	Author	Where Published	Date
*Drying in Superheated Steam	Tiemann, H.D.	Lumber World Review	Aug.10-'16
*The Casehardening of Wood	Tiemann, H.D.	Lumber World Review	July10-'16
*The Circulation in Dry Kilns; Parts 1, 2, 3, and 4	Tiemann, H.D.	Lumber World Review	May 10-'16 to Aug.10 1916
*Kiln Drying of Gum	Imrie, J.E.	Am. Lumberman So. Lumberman Hardwood Record Am. Furniture Mfr.	Jan. 22 Jan. 22 Jan. 25 1916
*Conditions Which Exist in Casehardened Wood	Imrie, J. E.	Hardwood Record Am. Lumberman	Nov. 10 Nov. 13 1915
*The Kiln Drying of Lumber	Tiemann, H.D.	St. Louis Lumberman Am. Lumberman So. Lumberman	Nov. 1 Oct. 30 Oct. 29 1915
*Improvement in Forest Service Humidity Regulated Dry Kiln	Tiemann, H.D.	Am. Lumberman Hardwood Record	Sept. 1 Sept. 5 Sept. 25 1915
*Problems in Kiln Drying Lumber	Tiemann, H.D.	Lumber World Review	Sept. 25 1915
*Effect of Different Methods of Drying on the Strength of Wood	Tiemann, H.D.	Lumber World	April 10, 1915

Note - The star before the name of an article indicates that no reprints are available for distribution. Such articles must be consulted in the original publication. Of the other articles, a limited supply of reprints are available for general distribution, and copies will be sent free upon application until the supply is exhausted. Application should be made to Director, Forest Products Laboratory, Madison, Wisconsin.

Title	Author	Where Published	Date
*Principles of Kiln Drying Lumber, Part 1 Part 2	Tiemann, H.D.	Lumber World Review	Jan.25 Feb.10 Feb.25 1915
*How to Dry Western Larch	Tiemann, H.D.	West Coast Lumberman	1914
*Kiln Drying Lumber and a Discussion of the whole Problem - A New Kiln	Tiemann, H.D.	Lumber World Review	Mar.10 1914
*Air Seasoning of Timber From Paper Contributed to Bul. 161, American Ry. Eng. Ass'n.	Kempfer, W.R.	Railway Review	Jan.10 1914
*Kiln Drying of Lumber Scientifically Considered	Tiemann, H.D.	American Lumberman	Nov.15. 1913
Eucalyptus Lumber Part 1. To What Extent is California Grown Eucalyptus Suitable for Lumber? 2. Results of Experiments in Drying Blue Gum and other Species	Tiemann, H.D.	Hardwood Record	Sept.25 1913
*Is Eucalyptus Suitable for Lumber?	Tiemann, H.D.	Proc. Soc. of Am. Foresters	Oct.1913

Physical Properties

Selecting Wood for Airplanes	Koehler, Arthur	Scientific Am. Supplement	Sept.6, 1919
*Effect of Moisture and other extrinsic factors on the strength of wood	Tiemann, H.D.	Society of Am. Foresters Proceedings - '07	1907

Identification and Structure

Title	Author	Where Published	Date
*Chemistry as an Aid in the Identification of Species	Schorger, A.W.	Proc. Soc. of Am. Foresters	Jan.'16
*A Plea for Closer Discrimination in the Use of the Words "Grain"and "Texture" With Respect to Wood	Koehler, Arthur	Hardwood Record	Feb.25, 1917
*A Visual Method of Distinguishing Longleaf Pine	Koehler, Arthur	American Lbrman. Engineering Rec.	Sept.11 Sept.11 1915
The "Grain"of Wood With Special Reference to the Direction of the Fibers	Koehler, Arthur	Aerial Age Weekly West Coast Lbrman Scientific Am. Supplement	Aug.12'18 July 15, 1918 Sept. 7, 1918
*An Improved Method of Infiltrating Wood With Celloidin	Koehler, Arthur	Proceedings of the Society of American Foresters	April 1914
*Microscopic Structure of Woods in Relation to Properties	Gerry, Eloise	Proc. Soc. of Am. Foresters	July 1913
*Microscopic Work of the Laboratory of Forest Products on the Structure of of Wood	Tiemann, H. D.	Am. Forestry	April 1911
*The Structure of Wood and Some of Its Properties and Uses	Gerry, Eloise	N. Hem. & Hardwood Ass'n.	Jan. 1916
*Wood Older than the Hills	Koehler, Arthur	Am. Lumberman Am. Forestry	Dec.25'15 Feb.'16

Title	Author	Where Published	Date
*Fiber Measurement Studies. Length Variations: Where They Occur and Their Relation to the Strength and Uses of Wood	Gerry, Eloise	Science N.S. Vol. XLI, No. 1048	Jan. 29, 1915
*Fiber Measurement Studies: A Comparison of Tracheid Dimensions in Longleaf Pine and Douglas Fir, with Data on the Strength and Length, Mean Diameter and Thickness of Wall of Tracheids	Gerry, Eloise	Science N.S. Vol. XLIII, No. 1106	Mar. 10, 1916
*Proper Methods of Turpentining Increased Yield Obtained Without Serious Injury to the Tree	Gerry, Eloise	Scientific Am. Supplement No. 2176	Sept. 15, 1917
*Bordered Pits in Douglas Fir: A Study of Position of Torus in Mountain and Lowland Species in Relation to Creosote Penetration	Griffin, G. J.	Journal of Forestry	Nov. 1919

Government Publications

Title	Date of Issue
"Effect of Moisture on the Strength and Stiffness of Wood", F.S.Bulletin 70 - 15 cents	1906
"Strength of Wood as Influenced by Moisture", F.S.Circular 108 - 5 cents	1907
"Properties and Uses of Douglas Fir, F.S. Bulletin 88 - 15 cents	1911
"The Specific Heat of Wood", F.S.Bulletin 110 - 5 cents	Sept.20, 1912
"Principles of Drying Lumber at Atmospheric Pressure and Humidity Diagram", F.S.Bulletin 104 - 5 cents	Dec.16 1912
"Tyloses: Their Occurrence and Practical Significance in Some American Woods", Published in Journal of Agricultural Research, 25 cents	Mar.25 1914
*"Density of Wood Substance and Porosity of Wood", Published in Journal of Agricultural Research 25 cents	Sept.21, 1914

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* Indicates supply is exhausted

Note - None of the above publications are available for general distribution from the Forest Products Laboratory. Any publication can be obtained from the Superintendent of Documents, Government Printing Office, Washington,D.C., at the price stated, until the supply is exhausted. Remittances should be made by money order, or in coin (at sender's risk); stamps can not be accepted. Publications out of print can be consulted at public libraries. In a number of cases they have been superseded by more recent publications.

Title	Date of Issue
"The Theory of Kiln Drying", U.S.D.A.Bulletin 509 - 5 cents	Mar.1917
"The Seasoning of Wood", U.S.D.A.Bulletin 552 - 10 cents	July 9, 1917
"Guidebook for the Identification of Woods Used for Ties and Timbers" - Miscellaneous Bulletin 30 cents	Oct.15, 1917
"Materials for the Household" Bureau of Standards Circular 70(Contains a chapter on Wood) - 25 cents	Dec.5, 1917